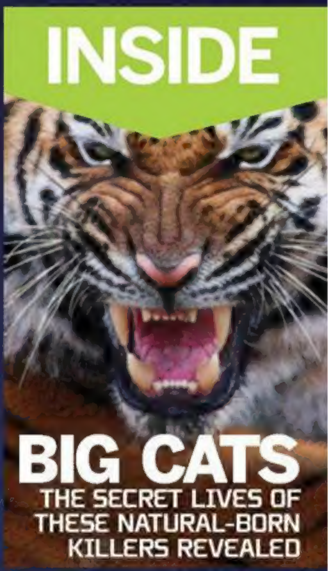
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE



BIG CATS

THE SECRET LIVES OF THESE NATURAL-BORN KILLERS REVEALED

SUPERSMART TVS

THE MOST RADICAL ADVANCES IN HOME ENTERTAINMENT

VOYAGE TO MARS

The greatest space mission since the Moon landings

SAMSUNG GALAXY S III

Inside the world's most exciting new device

995 FACTS AND ANSWERS INSIDE

EXTREME SUBMARINES

THE AMAZING VEHICLES EXPLORING NEW DEPTHS

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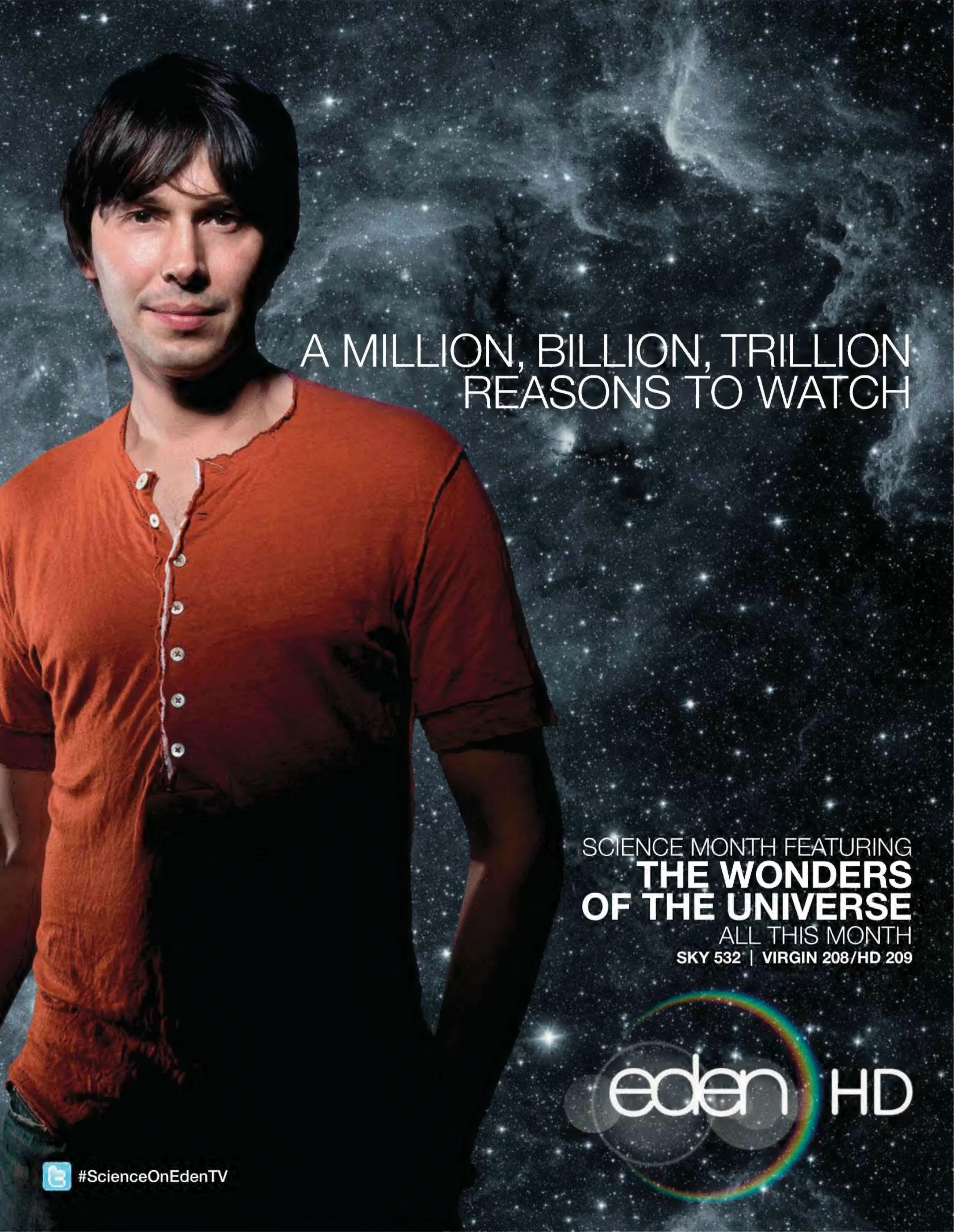

ISSUE 36

WELCOME

The magazine that feeds minds!

Get in touch

Have YOU got a question you want answered by the How It Works team? Get in touch by...

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FEED YOUR MIND!

It's a fact. We no longer simply 'watch' TV. While once we were content to sit in front of the box, viewing the programming timetable the broadcaster scheduled, today we want – no, demand – more. And the power is now in our hands... and faces and voices. I don't mean the power that holding the remote once granted over other people in the room, and I don't just mean the power to access, pause and rewind any movie you want to watch at will. Today we have the freedom to put down the remote and use things like gesture control and speech recognition to tell the TV what we want.

Not only that, but all major manufacturers now offer models with social network integration and internet connectivity as standard, so you can upload and share videos and photos, Skype friends and family, and much more besides. This all makes your TV a functional and convenient hub for communicating with the world. Televisions have got supersmart, so now's the time to find out how they work. Check them out on page 12.

Also this issue, you can discover the amazing technology behind NASA's Mars Science Laboratory mission, which is winging its way to the Red Planet as we speak. When it lands in August, the hunt for evidence of life on Mars will begin anew. One exciting mission to watch.

Enjoy the issue!

Helen

Helen Laidlaw
Editor

Meet the team...

Dave

Ed in Chief

Having just launched **All About Space** magazine I'm generally immersing myself in all things cosmic, and the feature on the latest intrepid mission to Mars is a great read.

Robert

Features Editor

This issue I relived the brutal Battle of Agincourt, which was romantic and horrific in equal measure. If there's a single conflict that vividly paints the grim realities of war, then this is it.

Ben

Features Editor

Several rovers have been sent to Mars, but I'm still fascinated by the technologies behind these missions. It's amazing to think that we can control robots on other planets.

Adam

Senior Sub Editor

From the incredibly resilient vehicles able to explore Earth's ocean depths to the weird creatures and geology you can find there, our submersible feature this month had me hooked.

THE SECTIONS

The huge amount of info in each issue of **How It Works** is organised into these sections

ENVIRONMENT
The splendour of the natural world explained

TRANSPORT
Be it road, rail, air or sea, you'll find out about it in Transport

HISTORY
Your questions about how things worked in the past answered

SCIENCE
Explaining the applications of science in the contemporary world around us

TECHNOLOGY
The wonders of modern gadgetry and engineering explained in depth

SPACE
From exploration of our Solar System to deep-space adventures

WITH THANKS TO...

How It Works would like to thank the following organisations for their help

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The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the experts in this month's edition of **How It Works…**

Shanna Freeman
Massive underwater mountains

Shanna delves deep into the subject of the Mid-Atlantic Ridge and explains the amazing geological processes that form the planet's largest mountain range, which happens to be in the Atlantic.

Nigel Watson
World's fastest RC car

Among other things, Nigel lifts the lid on the fastest remote-control car ever to be made, revealing how it can reach whopping speeds of 100mph plus. Whatever you may think of RC vehicles, this is no toy.

Luis Villazon
The big cats

Wildman zoologist Luis reveals seven deadly predators from the animal kingdom. Find out how the big cats stalk prey, how they hunt solo and in packs, and what they do all day in this comprehensive feature.

Aneel Bhangu
Seeing our thoughts

This issue surgeon Aneel explains how it's possible to 'see' what your brain is thinking in the various types of imaging technologies used in modern medicine. What can we glean from these pictures?

Tom Harris
The science of fear

It may sound funny to learn that some people in this world are afraid of beards, or of sitting down, but our bodies are wired to react to fear for a reason: to stay alive. Tom reveals how we deal with this lifesaving emotion.

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Supersmart TVs explained

Take a look inside some of the cleverest, most functional and desirable technologies leading the smart TV revolution in this issue's big Technology feature

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TRANSPORT

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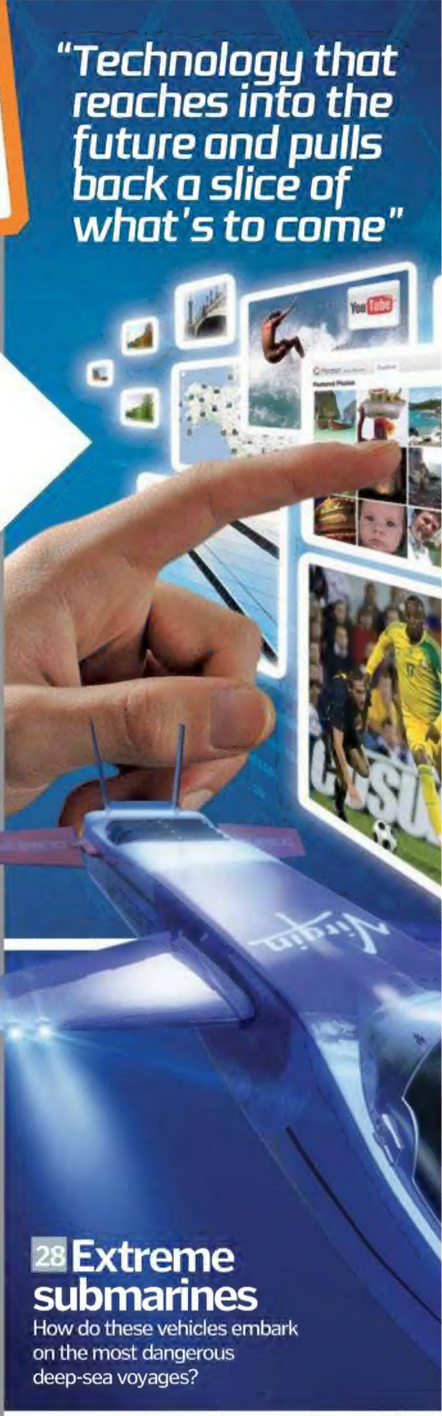
ENVIRONMENT

HISTORY

What powers the Samsung Galaxy S III smartphone?
Go to page 22 to find out!



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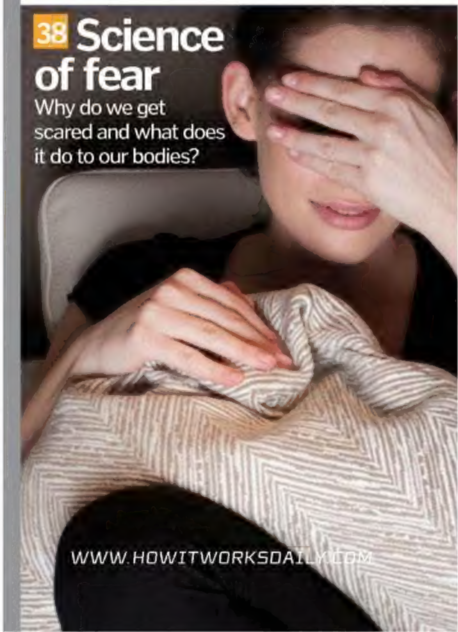

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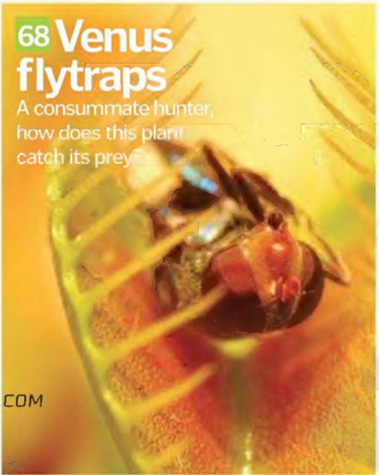

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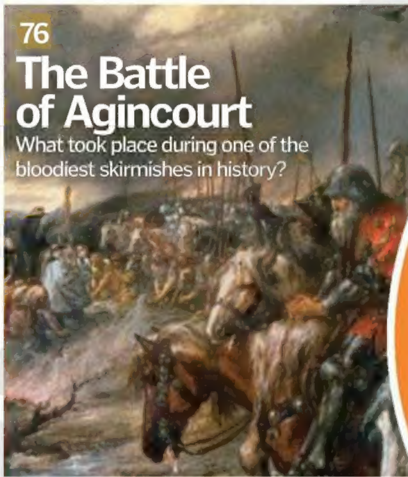

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The Battle of Agincourt

What took place during one of the bloodiest skirmishes in history?

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How lightning sparked Colorado's inferno

A colossal wildfire has laid waste to a nature reserve in Colorado, so far consuming over 60,000 acres of woodland and causing an estimated $12.6m (£8m) damage

In what is predicted to be the largest wildfire Colorado has ever seen, over 24,280 hectares (60,000 acres) of protected forest and at least 189 residential homes have now been burnt to the ground. Started by a lightning strike on 9 June and driven by high winds and soaring temperatures, at the time of writing, firefighters were still battling to quell the spreading blaze, which has seen mass evacuation of the region, road closures and utility services brought to their knees.

Wildfires begin naturally from four major causes: lightning strikes, volcanic eruptions, sparks from rockfalls and, rarely, spontaneous combustion. Once instigated, the fires then take the form of one of four main fire types, dependent on burn height and fuel consumption. Ground fires feed off subterranean roots and organic matter, surface fires off low-level vegetation such as grasses, ladder fires climb upwards consuming small trees, while crown fires burn and spread through forest canopies. It is typical for wildfires to progress between these types, driven largely by environmental factors such as wind and temperature.

Speaking on the efforts to counteract the wildfires, Brett Haberstick of the federal incident management team said: "The interior is still very hot. This isn't a single battle; this is a campaign. Mother Nature [has been] pretty tough on us."

At the time of writing, the wildfires were still spreading through the High Park area in central Colorado, with no sign of abating any time soon; as such, officials are still unwilling to allow residents to return to their properties. Speaking on the evacuation, John Schulz, spokesperson for the Larimer County Sheriff's Office, said authorities couldn't risk allowing people to return in case the fire turns back, as it is currently only 55 per cent contained. Most worrying of all, however, was a warning from the region's weather service, which stated: "Record or near-record heat combined with an extremely dry air mass and breezy conditions will create a very high fire danger. Conditions will be favourable for rapid growth of existing wildfire and new fire starts." The firefighting operation continues.

© Kari Greer

Thousands of acres of forest have been consumed by the fire, along with nearly 200 homes

© Getty Images

> "The interior is still very hot. This isn't a single battle; this is a campaign. Mother Nature [has been] pretty tough on us"

On Mars the contestants would be exposed to a huge amount of ionising radiation, which the show says it will counteract with large radiation shields

© NASA

TV show aims to touch down on Mars by 2023

A new venture will offer members of the public a chance to live on the Red Planet

In what is being dubbed as both 'the biggest hoax of all time' and also 'a brave attempt to challenge the boundaries of space travel', a new reality TV show led by Dutch entrepreneur Bas Lansdorp intends to establish the first colony on Mars in 2023.

The project, named Mars One, intends to generate $6 billion (£3.8 billion), put out an open call for applicants, train a select few of them over a seven-year period and then fire them off to the Red Planet. Upon arriving, they will meet a Mars One rover – which will have been sent during the training programme to ascertain the best place to establish a settlement – and proceed to set up the first permanent dwelling. Importantly, each stage of the project will be recorded live and any footage will be transmitted back to Earth for the creation of a reality TV show.

Speaking on the critical commentary Lansdorp said: "If you look at the team involved in Mars One, none of us would do this as a hoax. If a Mars mission was to happen we'd want to be part of it and if we did a scam now no one would ever include us in the real thing."

Despite a number of scientists and academics becoming ambassadors for the project, commentators are stating that Mars One grossly underestimates the levels of technology and finance required for such an ambitious venture.

Amazing new space launch!

All About Space is the brand-new magazine taking readers on a wondrous journey through the cosmos

Imagine Publishing has bolstered its knowledge portfolio with a fantastic new magazine dedicated to explaining the wonders of the universe. **All About Space** delivers the most authoritative and cutting-edge facts, opinion and news from the field, with the help of an expert panel of space journalists and industry professionals. From the current search for a new Earth to the next-gen space planes set to take humans to the farthest reaches of the galaxy, **All About Space** has it all.

Speaking on the launch, Editor-In-Chief Dave Harfield said: "**All About Space** is the most exciting magazine launch since **How It Works**. Space is a mindblowing topic and we're confident anyone fascinated by the cosmos will find **All About Space** the most amazing space magazine in this world or, indeed, any other."

All About Space is available now to download at **www.greatdigitalmags.com**, or you can buy the magazine online at the Imagine eShop or from all good supermarkets. For an exclusive preview of issue one visit **www.spaceanswers.com** today.

GLOBAL EYE NEWS

WHAT ON EARTH IS IT?

A close-up look at the world!

Each month we post some weird images on the HIW website. Find out what they are now...

1. What is it?

Your best answers:

'It's an alien's face!' – **Alex Woolley**

'The head of a very strange insect' – **Ashwin Kumaar**

A: Green bush-cricket

© Didier Descouens

This weird-looking creature is a green bush-cricket, which is a long-horned katydid of the tettigoniidae family. There are over 6,400 recorded species of bush-cricket on Earth, ranging from North America, through Europe and down to the tropics. The majority of bush-crickets consume mainly leaves, flowers and bark, however some are exclusively predatory, feeding instead on other insects and snails.

2. What is it?

Your best answers:

'Some sort of jelly monster?' – **Ben Swindell**

'Looks like a blue-ringed octopus, but maybe it's a cuttlefish?' – **Quinnlan Hatchett**

A: Reef cuttlefish

© Nhobgood

This is a broadclub cuttlefish (sepia latimanus), which is commonly referred to as a reef cuttlefish due to it being the most common to be found in coral reefs. The broadclub is the second-biggest species of cuttlefish in the world, often growing to 0.5 metres (1.6 feet) long and weighing in excess of ten kilograms (22 pounds). It feeds primarily on shrimp, prawns and other small marine creatures.

3. What is it?

Your best answers:

'An insect's nest?' – **Bradley Lynham**

'The remains of a T-rex TV dinner?' – **Christopher Attwood**

A: Brachiopod

© Didier Descouens

This is a fossilised Early Jurassic period brachiopod with its lophophore skeleton visible within. The lophophore is a characteristic feeding organ of brachiopods that helps them collect micro-plankton and other tiny organisms; it consists of a series of ringed, hair-like tentacles that line its mouth.

To get involved, visit WWW.HOWITWORKSDAILY.COM to make your guess now!

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THIS DAY IN HISTORY

12 JULY: How It Works issue 36 goes on sale, but what else

927 Æthelstan, King of England, secures a pledge from King Constantine of Scotland that he will not ally with the Vikings.

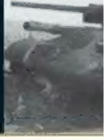
1191 During the third crusade, Sultan of Syria Saladin's garrison at Acre surrenders to Philip Augustus, ending a two-year siege (right).

1543 King Henry VIII marries his sixth and final wife, Catherine Parr, at Hampton Court Palace.

1860 The Medal of Honor is authorised by the US Congress.

1920 The Soviet-Lithuanian Peace Treaty is signed.

1943 The Battle of Prokhorovka takes place between German and Soviet forces, the largest-ever tank engagement.



Rise of US insect spy drones causes a buzz

The US military is to introduce minuscule robotic spies this year, with lethal mini-drones expected by 2015

The US military has confirmed that it is to adopt robotic insect-sized spies 'as tiny as bumblebees' that can fly into enemy buildings and record images and audio this year. In addition, the US Air Force has confirmed that it is currently working on 'lethal mini-drones' that would begin to be rolled out in 2015, each capable of attacking insurgents and targets.

Interestingly, unlike today's large-scale UAV drones that have been used in the recent Iraq and Afghanistan conflicts, these new insect-sized drones will heavily imitate nature through nanobiomimicry, apeing the eye, ear, wing and body structures of bats, birds and beetles among other creatures.

Speaking on the reasons to imitate nature in these drones, Professor Richard Bomphrey of Oxford University said: "Nature has solved the problem of how to design miniature flying machines. By learning those lessons, it [will be] possible to aerodynamically engineer a new breed of surveillance vehicles that, because they are as small as insects and also fly like them, completely blend in to their surroundings."

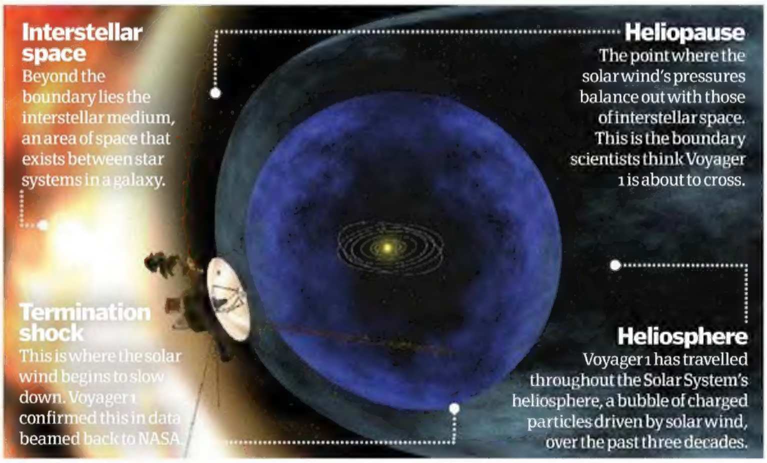
Although this is just a concept, these new insect-sized drones will heavily imitate nature through nanobiomimicry

Voyager 1 to exit Solar System

After 35 years of continuous spaceflight, the Voyager 1 probe is close to entering interstellar space, according to NASA

NASA's Voyager 1 spacecraft, which launched on 5 September 1977, is about to leave our Solar System. The probe is currently experiencing a sharp rise in the number of high-energy particles hitting it from distant exploded stars, a tell-tale sign it is on the boundary of interstellar space. Speaking on the report, Ed Stone, a Voyager project scientist at the California Institute of Technology, said: "The latest data indicates we are clearly in a new region where things are changing more quickly. It is very exciting. We are approaching the Solar System's frontier. The laws of physics say that Voyager will become the first human-made object to enter interstellar space, but we still don't know exactly when that will be."

Voyager 1 runs on a plutonium power source that's predicted to last for another 10-15 years.



Interstellar space
Beyond the boundary lies the interstellar medium, an area of space that exists between star systems in a galaxy.

Heliopause
The point where the solar wind's pressures balance out with those of interstellar space. This is the boundary scientists think Voyager 1 is about to cross.

Termination shock
This is where the solar wind begins to slow down. Voyager 1 confirmed this in data beamed back to NASA.

Heliosphere
Voyager 1 has travelled throughout the Solar System's heliosphere, a bubble of charged particles driven by solar wind, over the past three decades.

Digital downloads available on supersite

The entire Imagine portfolio of magazines is now available on a new supersite

Do you read several Imagine magazines each month? Of course you do, they are the most entertaining, authoritative and best-value-for-money magazines on the market. Well, now you can feed your obsession for quality journalism by picking up every glorious issue in digital format at **www.greatdigitalmags.com**, a new website where you can discover the vast Imagine digital portfolio all in one handy place. From authoritative knowledge titles like the brand-new **All About Space** and the creative extravaganza that is **3D Artist** to the latest sci-fi news in **SciFi Now**, this site has it all. So, whether you have an iPad, iPhone, Android smartphone or tablet, Windows Phone 7 or simply a PC, head to **www.greatdigitalmags.com** now and enter a heavenly new realm of infotainment.

> *"The Imagine portfolio all in one handy place"*

happened on this day in history?

1962 The Rolling Stones perform their first concert at the Marquee club, London (right).

© Kiwi/Tanet

1970 A fire consumes 90 per cent of Norwegian composer Geirr Tveitt's life's works.

1979 The island nation of Kiribati in the Pacific becomes independent from Great Britain.

2007 Footage is leaked of US Army Apache helicopters performing airstrikes in Baghdad, Iraq.

1943 image © Bundesarchiv, Bild 101I-219-0553A-36

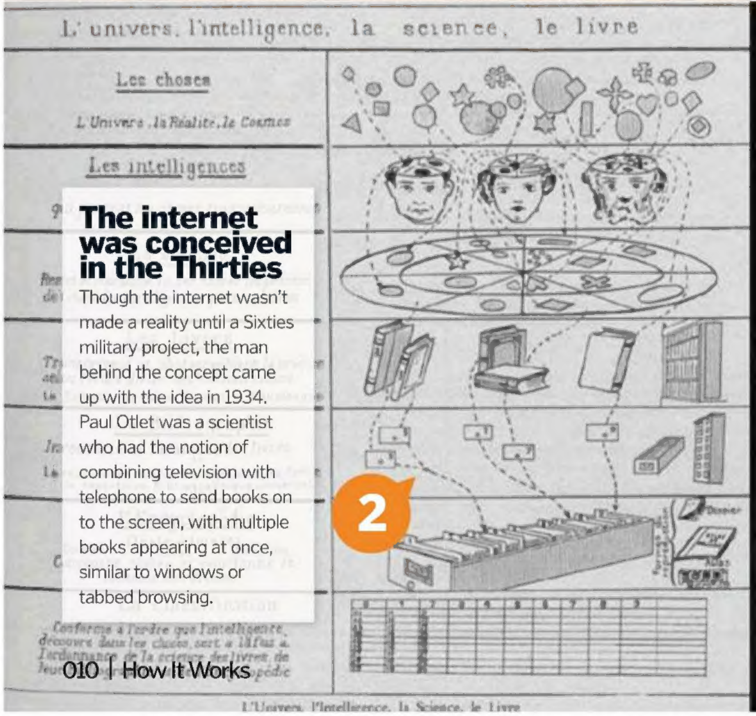
10 COOL THINGS WE LEARNED THIS MONTH

AMAZING TOPICAL FACTS...

Corpse flower steals host's DNA

Scientists have discovered that the parasitic Malaysian rafflesia (also known as the corpse flower for the stench it emits) steals large chunks of DNA from its host (a vine), mimicking the process by which plants and animals pass their genes on. It was originally thought that the DNA stolen was used by rafflesia to prevent its host attacking it, but the commandeered genes fulfil a wide variety of functions.

© SPL



The internet was conceived in the Thirties

Though the internet wasn't made a reality until a Sixties military project, the man behind the concept came up with the idea in 1934. Paul Otlet was a scientist who had the notion of combining television with telephone to send books on to the screen, with multiple books appearing at once, similar to windows or tabbed browsing.

'Twisted' light Wi-Fi is superfast

Researchers have found a way of 'twisting' light to create Wi-Fi and optical fibre speeds of up to 2.5 terabits a second. By manipulating the orbital angular momentum of the waves, sending out the signal in a corkscrew shape, traditional broadband media can clock up the equivalent speed of copying 60 or so DVDs in merely a second.

Big oyster could be a profitable catch

If you've just found an oyster, there is part of you that hopes that you'll find a pearl inside, however slim your chances. So if you find a 100-million-year-old oyster, ten times the size of today's... Well, that's what fishermen discovered in their nets while dredging the Solent in south England. The Jurassic fossil will undergo an MRI scan to determine whether it contains a pearl that, potentially, could be the size of a golf ball.

Lamps can be powered by blood

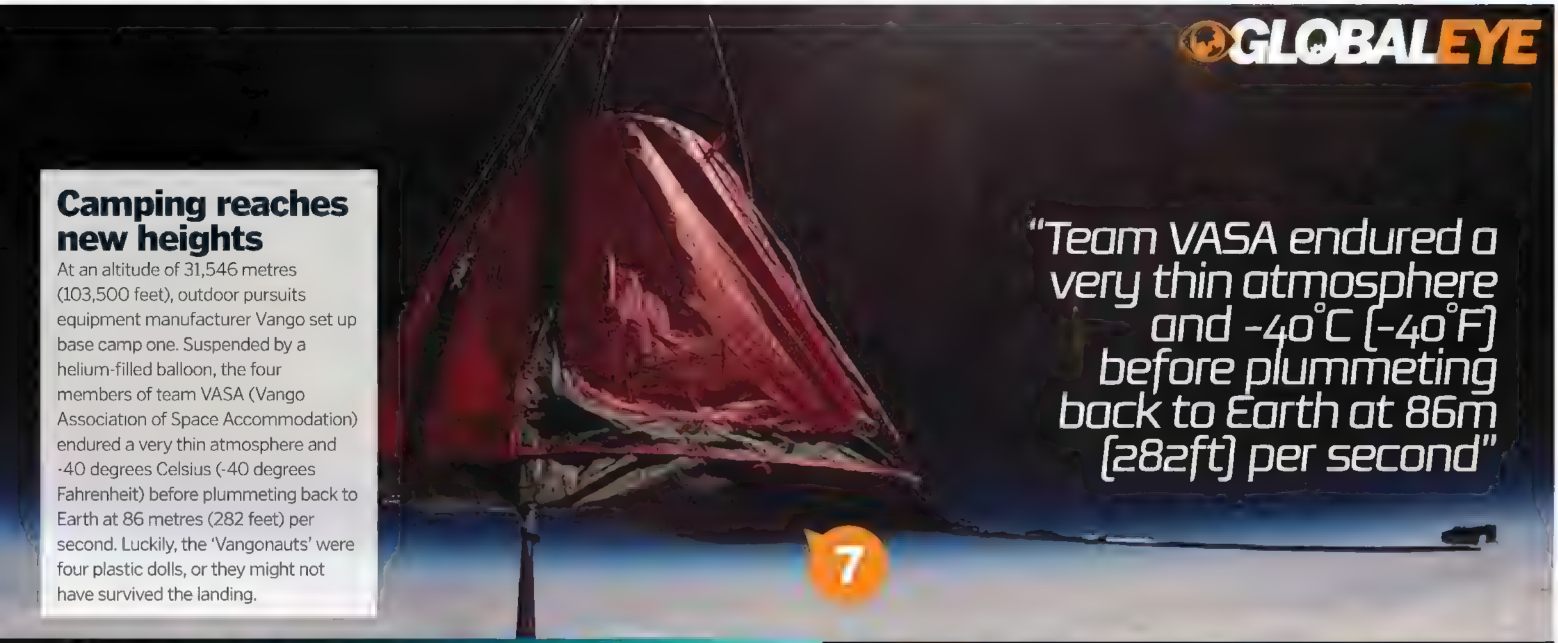
Artist Mike Thompson created a single lamp that glows when energised by a few drops of blood. You simply break the glass top off and use the sharp edge to pierce your skin, allowing the blood to drip into the ampule of chemicals. It's intended to force us to 'rethink how wasteful' our disposable society is.

© miket.co.uk

Supermassive black hole isn't welcome

A galaxy around 4 billion light years from Earth is in the process of ejecting a supermassive black hole at its centre. NASA scientists have proposed that the black hole, millions of times the mass of the Sun, had merged with another black hole which has resulted in a recoil kick that is ejecting it at several million miles per hour.

© NASA



Camping reaches new heights

At an altitude of 31,546 metres (103,500 feet), outdoor pursuits equipment manufacturer Vango set up base camp one. Suspended by a helium-filled balloon, the four members of team VASA (Vango Association of Space Accommodation) endured a very thin atmosphere and -40 degrees Celsius (-40 degrees Fahrenheit) before plummeting back to Earth at 86 metres (282 feet) per second. Luckily, the 'Vangonauts' were four plastic dolls, or they might not have survived the landing.

> "Team VASA endured a very thin atmosphere and -40°C (-40°F) before plummeting back to Earth at 86m (282ft) per second"

Human ancestry looks fishy

A prehistoric fish from before the dinosaurs has been linked to homo sapiens as an ancient ancestor. Acanthodes bronni is a 300-million-year-old 'jaw-mouth' with large eyes from which thousands of today's vertebrates are descended. It existed before bony fishes and early sharks made their genetic departure from each other.

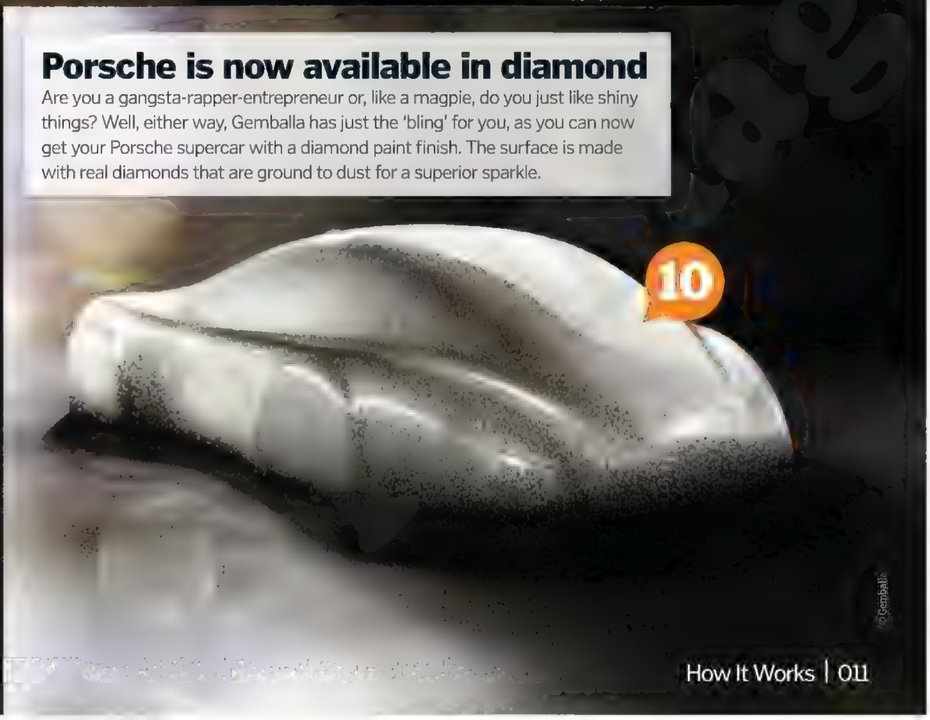
There's not much water on Earth

Around 70 per cent of the Earth might be covered by water, but even the deepest oceans are shallow compared with the radius of the planet. So, if you took all the water on Earth and put it together, its radius would measure just 700 kilometres (435 miles) – less than half that of the Moon. However, we still don't know for sure whether a large body of water is trapped deep beneath the surface.

© NASA

Porsche is now available in diamond

Are you a gangsta-rapper-entrepreneur or, like a magpie, do you just like shiny things? Well, either way, Gemballa has just the 'bling' for you, as you can now get your Porsche supercar with a diamond paint finish. The surface is made with real diamonds that are ground to dust for a superior sparkle.



©Gemballa

Home entertainment evolved

Welcome to... TECHNOLOGY

Televisions have changed radically from the 'idiot boxes' of yesteryear, as we see here. We also discover how inhalers save lives, what's inside the Galaxy S III phone and how vacuum cleaners have evolved

18 Water turbines

22 Galaxy S III

24 Starting blocks

LEARN MORE

Evolving TVs are positioning themselves at the heart of their owner's digital life, offering amazing levels of connectivity, as well as delivering a host of dynamic ways to interact with them

SUPERSMART TVS

It's a well-known fact that technology iterates. It continually gets better, faster and more functional. This is true across all its forms, offering consumers tools and gadgets that can make their lives easier and more enjoyable. Importantly though, what is also true is that more often than not these iterations are merely incremental improvements, offering largely the same product as before but ever so slightly tweaked. Maybe the technology is slightly faster – for example, a 2.6GHz CPU over a 2.5GHz one in a computer – but it is not delivering something radically new; it does not offer a road map for future advancement.

At other times, a game-changer comes along. A piece of technology that reaches into the future and pulls back a slice of what's to come – a recent example, arguably, might be Apple's Siri personal assistant. The smart TV is about to do the same for consumer televisions. By converging the TV's traditional high-resolution display with the computational power, connectivity and software of a PC, as well as the motion-control abilities of next-gen consoles and the type of voice-recognition and command systems made famous by Siri, smart TVs are soon to be the digital heart of every household.

From cloud computing, data storage, email and social networking, on to exercising regimes and games, through to video calling, word processing and weather reports, this new generation of televisions offers users the potential to collapse a plethora of electronic devices into one central hub, streamlining their day-to-day activities and blurring the lines between a work and leisure device. To see how smart TVs are set to accomplish this, How It Works takes a look at today's most cutting-edge unit, the Samsung ES8000 S8, exploring its hardware, software and features which are transforming the 'idiot box' into something altogether more clever.

5 TOP FACTS
SMART TELEVISIONS

Marketing

1 'Smart TV' is a marketing term to loosely describe a television that connects to the web and sports modern features and functionality such as gesture control.

Perspective

2 Today's top-end smart TVs output at a resolution of 1,920 x 1,080px, which is considered hi-def. However, 4K televisions already exist that more than double this resolution.

Siri

3 One of the hottest rumours currently circulating is that iPhone manufacturer, Apple, is working on a smart TV of its own and intends to incorporate its Siri personal assistant software into it.

Convergence

4 The current shift towards smart TVs is led by the concept of technological convergence, a bringing together of technology found in computers, televisions and set-top boxes into a single unit.

Open source

5 All smart TVs come with their own operating system via which the unit's apps and features may be run. These operating systems are mostly based on Linux or other Android variants.

DID YOU KNOW? The ES8000 enables users to pull pictures, videos and music wirelessly from a mobile device

Benefits of a smart TV

Combining the functions of many modern-day appliances, is this the ultimate device?

2x © Samsung

Personal computer

Smart TVs incorporate components traditionally found in PCs, such as hard drives, processors, memory and cooling fans/panels, letting users store and access media and data files.

Games console

In-built camera motion-detection capabilities, plus a variety of digital app stores, allow games and fitness applications like those demonstrated on Xbox Kinect to be accessed.

Mobile phone

Thanks to the voice-recording and recognition hardware, as well as high-definition integrated web cameras, smart TVs also enable users to make voice and video calls via Skype.

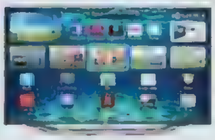
HD TV

Of course, smart TVs also mean users can enjoy their usual TV shows in standard-definition, high-definition or 3D, the latter made possible via active-shutter 3D glasses included with most models.

Tablet

Accessing websites via a capacitive touch panel is a key selling point for tablets. The smart TV takes it one step further by making online content accessible via both gesture and voice controls.

The statistics…



Samsung ES8000 S8

Width: 1,230.3mm (48.4in)
Height: 722.3mm (28.4in)
Depth: 30.8mm (1.2in)
Weight: 25.4kg (55.9lb)
Screen size: 1,397mm (55in)
Resolution: 1,920 x 1,080px
Display type: LED
Bezel: Aluminium
Power supply: AC220 – 240V (60Hz)

The new remote controls

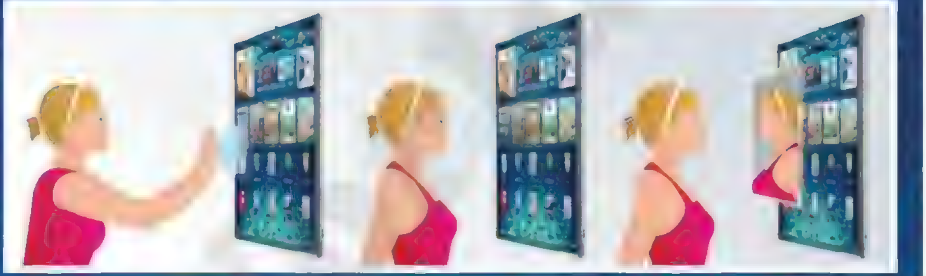
Samsung's ES8000 typifies an industry-wide push towards gesture control, as well as voice and facial recognition, but how do they work?

The ES8000's ability to be manipulated by gestures is thanks to a motion-tracking camera. The camera automatically detects users in front of the screen and then locates and tracks hand movements. When the TV is on, the user activates gesture control by waving once; this locks the on-screen cursor to the user's hand. Then you can navigate the screen and its options by simply moving your hand. To simulate a cursor select, the user just closes and opens their palm.

While we are talking about the ES8000's camera, it also functions as a recogniser for the set's facial-recognition software. This can be used for Skype video calls, or for a facial login to the user's personal Smart Hub account. As with gesture control, this works by the camera automatically detecting the user's face with a mapping tool, and then matching their characteristics with those calibrated on the set.

Voice control is equally advanced and is made possible by a wireless IR blaster; this is a small cone-shaped peripheral that connects to the TV wirelessly via Bluetooth and communicates with the set-top box (satellite or cable, for example) to grant control over volume and channels, among other things. This is especially important, as without it, the ES8000's voice control would be limited to crude up/down commands.

A selection of pre-programmed instructions each activate different aspects of the television's and set-top box's control schemes. Voice control is initiated by the user saying, "Hi, TV". Once this has been activated, it offers fine management of channel selection, volume and power, as well as several other functions. For instance, if you wanted to change from channel 3 to 27, you'd simply say, "Hi, TV. Channel 27." The voice-control function even lets users vocally log in and out of various accounts and services.



> "Samsung has integrated its own app store – Samsung Apps – directly into the Smart Hub"

Maximum connectivity

Smart TVs offer a direct portal to the internet, creating a whole new way to surf the web

Sharing

One of the top features of Samsung's Smart TVs, the ES8000's AllShare software allows users to push content wirelessly to the screen or pull content off it and on to a smartphone or tablet via a home network. The former works by simply selecting a file from the handheld device, activating the AllShare option on a submenu, and then dictating a destination. As such, if a user has recorded a video on their smartphone, they can quickly share the content with others on the TV's far larger screen. In contrast, the pull feature enables a user to drag specific TV channels from the set's screen on to a tablet, so you don't miss a moment.

Apps

Samsung has integrated its own app store – Samsung Apps – directly into the Smart Hub UI. These apps are largely small tools for streaming content, playing games or accessing online info – eg news sites – rather than the large-scale varieties found on the App Store or Google Play. But due to the customisable nature of the Smart Hub, they can be positioned on the home screen and operated via the ES8000's gesture and voice-control functions.

Video

On-demand and video-streaming services are directly accessible through the Smart Hub or a selection of applications. These allow content to be streamed wirelessly over the internet at 1080p directly on to the screen and, most importantly, without the need for a dedicated TV service provider. The ES8000 is also tailored for video playback from perennially popular sites like YouTube, with all resolution videos capable of being streamed live.

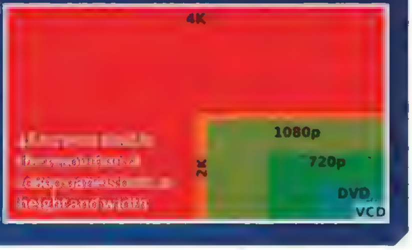
Social networking

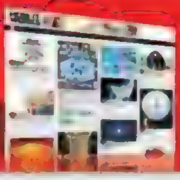
Along with a direct internet connection, the ES8000 provides both in-browser access to social-networking sites like Facebook and Twitter, as well as dedicated UI applications. Uniquely though, thanks to the unit's dual-core CPU, picture-in-picture functionality allows these social-networking sites to be open alongside a TV channel, enabling users to comment on programmes as they are being broadcast so they can update their status accordingly.

The race to 5K

Next-generation TVs are leaving 'HD' resolutions in their dust, doubling and tripling them over colossal panels

While today TVs are marketed on their ability to output images at 'HD' resolutions – maxing out at 1080p (1,920 x 1,080) – the future of consumer products promises far greater resolutions. Indeed, showpiece panels already have been developed that output images at twice, or even three times, those figures. 4K screens – named due to their horizontal resolution of approximately 4,000 pixels – more than double that of 1080p screens, and as such, allow for crisp image reproduction on far bigger units. A good example is the Panasonic TH-152UX1, which delivers 4,096 x 2,160 across a 386-centimetre (152-inch) set. Despite its awesome size and resolution, the UX1 costs $500,000 and is made to order, so screens like this won't be going mainstream anytime soon. Regardless though, the UX1 gives a taste of the current race to 5K – a race that is accelerating at a furious rate due to many filmmakers already shooting on 5K video cameras (such as on *The Hobbit*).

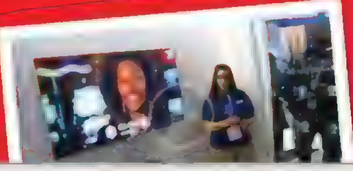




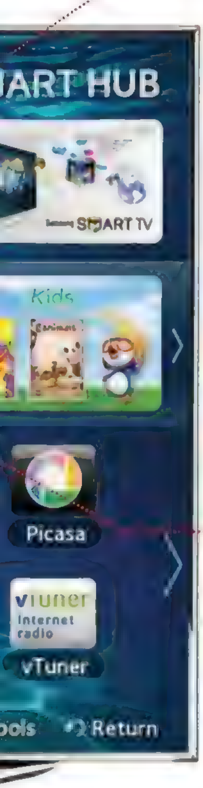
AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Witness the Smart TV's voice/gesture controls

www.howitworksdaily.com



DID YOU KNOW? The ES8000 has an 800Hz clear motion rate (CMR), which helps to prevent blur in fast-moving images



© Samsung

Cloud computing

The ES8000 ships with 5GB of cloud storage per user, which can be accessed via the Family Story app. This lets users upload photos, video and audio files to the cloud and store them remotely. As such, the cloud data repository can be accessed by more than just the TV itself, with content accessible via Samsung smartphones and tablets. In addition, these auxiliary devices can also upload content to the cloud repository directly and remotely, enabling, for example, a user to upload photo content while away on holiday and allow another family member – who couldn't make the trip – to access it instantly via the home TV.

Fitness

One addition that makes great use of the ES8000's motion-tracking camera is the Smart Hub's Fitness software. This acts in a similar way to activity-based games released on Microsoft's Kinect console add-on, dictating a wide variety of exercises to complete and then tracking your progress. As the user is exercising, the set's camera generates an artificial mirror, presenting a video stream on an overlay next to their virtual instructor, helping you to copy their actions. This is signed in and out of via the facial login, so individual accounts can be set up.

Is 3D TV dead?

The marketing has largely fallen on deaf ears over the past three years – so does 3D TV have a future?

'3D TV' currently relies on a user wearing one of three types of 3D glasses: anaglyphic, polarised or alternate-frame sequencing. The former two are passive technologies, using a series of filters to encode an image for each of the eyes to generate a mild 3D effect, while the latter is an active technology and the one currently being taken up by smart TVs. This active sequencing works by opening and closing minuscule shutters in the glasses to alternately present an image to the left and right eyes in sequence. These glasses do this so rapidly that the perceived 2D images fuse into a single 3D one.

Critically, however, all of these technologies have certain issues. First, for any user to perceive a 3D effect they need a pair of glasses, which are often very expensive. Second, the glasses – if active – require batteries to operate, adding to the lifetime expense of the unit. Third, all types darken the viewed images dramatically, leading to less vibrant pictures or requiring the television to overcompensate, outputting images at incredibly bright and saturated levels.

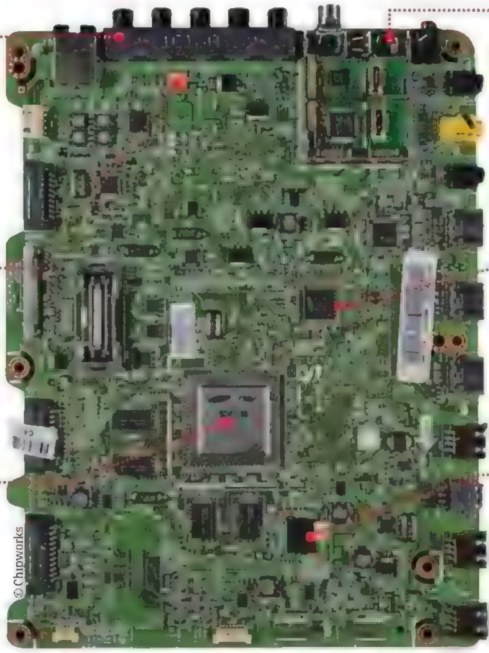
The future of 3D, however, is far from over, with a new push to produce glasses-free 3D TVs. These prototype models adopt an evolved form of the autostereoscopy used in the Nintendo 3DS games console, but, unlike the 3DS, they allow 3D to be perceived at more than one central viewing angle. These sets do this in a variety of ways, but the one with most traction so far is a motion-tracking camera, which follows a viewer's eyes and repositions the 3D effect accordingly.

Right now high-end smart TVs come bundled with active-shutter 3D glasses

© Panasonic

Semiconductor heaven

Bells and whistles aside, the advanced circuitry is the real brains of smart TVs



© Chipworks

Conexant voice recognizer
Voice recognition on the ES8000 comes courtesy of a Conexant voice input processor, which is positioned along with the circuitry needed for sound reproduction on a secondary board.

Wi-Fi module
While the ES8000 has an Ethernet input for a hard-wired internet connection, it also comes with a Ralink 5572N Wi-Fi module, which allows the set to connect wirelessly to the user's router too.

Digital Natural Image engine
The DNIe chip uses four proprietary processes – a motion optimiser, contrast enhancer, detail enhancer and colour optimiser – to boost image and sound quality.

Expansion port
This TV comes with a rear-mounted expansion port, which is included to allow its firmware and hardware to be augmented with an evolution module in the future. This means that the set can be upgraded periodically.

LCD timing controller
The timing controller chipset optimises the screen's pixel refresh timing, ensuring the generation of consistent image reproduction at all times.

Frame rate controller
The SDP1111 frame rate controller allows the LED panel to produce over 16 million colour shades through dithering, a method that combines adjacent pixel colours for shade simulation.

As we have seen, the ES8000 S8 Smart TV from Samsung offers a boatload of next-generation features, ranging from motion and voice control, through cloud computing and on to an app-tacular Smart Hub user interface. Importantly though, all of these rely on – and indeed would be useless without – a selection of advanced physical hardware, which luckily the S8 has in spades.

In fact, when you take the unit apart, it's easy to see how this device is significantly more advanced than a stock HD TV. From memory modules and application processors through to imaging technology, the ES8000 is stuffed with some hot semiconductor tech. All over the main board, which is housed in a pure aluminium shell – as well as over a brace of subsidiary ones – a mountain of silicon can be found, plus a couple of items that even use the latest generation of 32-nanometre high-k/metal-gate (HKMG) material. Take a look at the teardown for some of the key components of this awesome hardware.

> "The ES8000 Smart TV is stuffed with some hot semiconductor tech"

“To improve the car’s handling, its shock absorbers are held in stiff aluminium shock towers”

The remote-control supercar up close

What’s inside the speediest ready-to-race RC car?

The Traxxas XO-1 can rocket from 0-97 kilometres (0-60 miles) per hour in 2.3 seconds and, just as impressively, 0-161 kilometres (0-100 miles) per hour in merely 4.92 seconds.

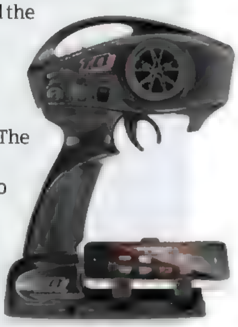
Its incredibly high performance is due to a lithium polymer (LiPo) battery-powered motor that engages with an all-wheel drivetrain, which transmits the power to the front and rear gearboxes. At each end, the car features a bespoke Cush Drive damper between the spur gear and drive hub that flexes to absorb the load created by high-traction acceleration. To improve the smoothness of the ride and handling of the car, its shock absorbers are held in stiff aluminium shock towers.

Being a low-slung, 1:7 scale model that is 686 millimetres (27 inches) long by 300 millimetres (11.8 inches) wide, it has a large and stable platform that delivers much better stability and handling compared to 1:10 scale cars. In addition, it has a smooth undertray and one-millimetre (0.04-inch) polycarbonate aerodynamic body with an injection-moulded rear wing to convert airflow into downforce while simultaneously minimising drag.

For maximum performance, durability and efficiency, the XO-1’s gears are eight millimetres (0.32 inches) wide and the teeth are bigger than those of conventional electric RC cars. The slick tyres are also composed of soft compound rubber to deal with the immense speeds.

Using the Traxxas Link App, connected to an Apple iPhone or iPod touch that’s docked in the controller, fine adjustments can be made to the car, and telemetry data from the XO-1, such as RPM, temperature and battery voltage, can all be viewed in real-time.

Radio control system

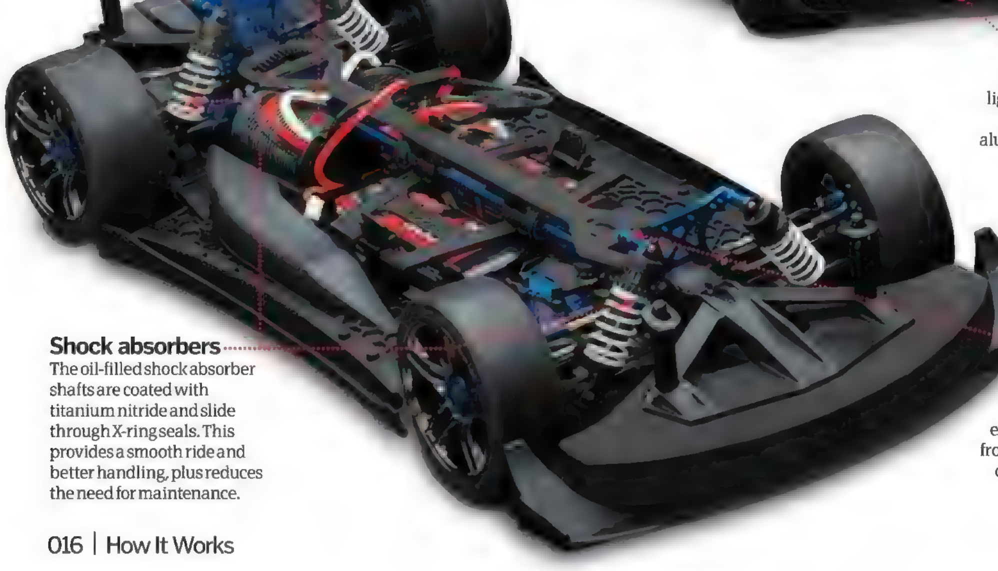


The TQi control transmitter sends out a powerful 2.4GHz signal to the five-channel micro-receiver inside the supercar. Two of these channels control the speed and steering, and it has three telemetry ports that send real-time sensor data back to the controller.

The controller is powered by four AA batteries and has an internal antenna. The main controls are a trigger-operated throttle and a steering wheel. Tweaks to the sensitivity of the steering, throttle and braking can all be made using a docked iDevice, via a hi-def colour display, which also presents real-time stats on things like speed and RPM.

Inside the Traxxas XO-1’s body

What under-the-hood engineering powers this miniature racer?



Motor The Big Block Brushless Motor, with premium-quality bearings, consists of neodymium magnets contained in a heat-dissipating unit.

Chassis The XO-1 has strong yet lightweight 3mm (0.12in)-thick upper and lower aluminium chassis decks.

Shock absorbers The oil-filled shock absorber shafts are coated with titanium nitride and slide through X-ring seals. This provides a smooth ride and better handling, plus reduces the need for maintenance.

Drivetrain The hollow and lightweight, extruded aluminium drivetrain engages directly with the front and rear gearboxes. It delivers power to all four wheels of the car.

The statistics…

Traxxas XO-1

Engine: Big Block Brushless Motor

Power: 2 x Traxxas Power Cell 5,000mAh LiPo batteries

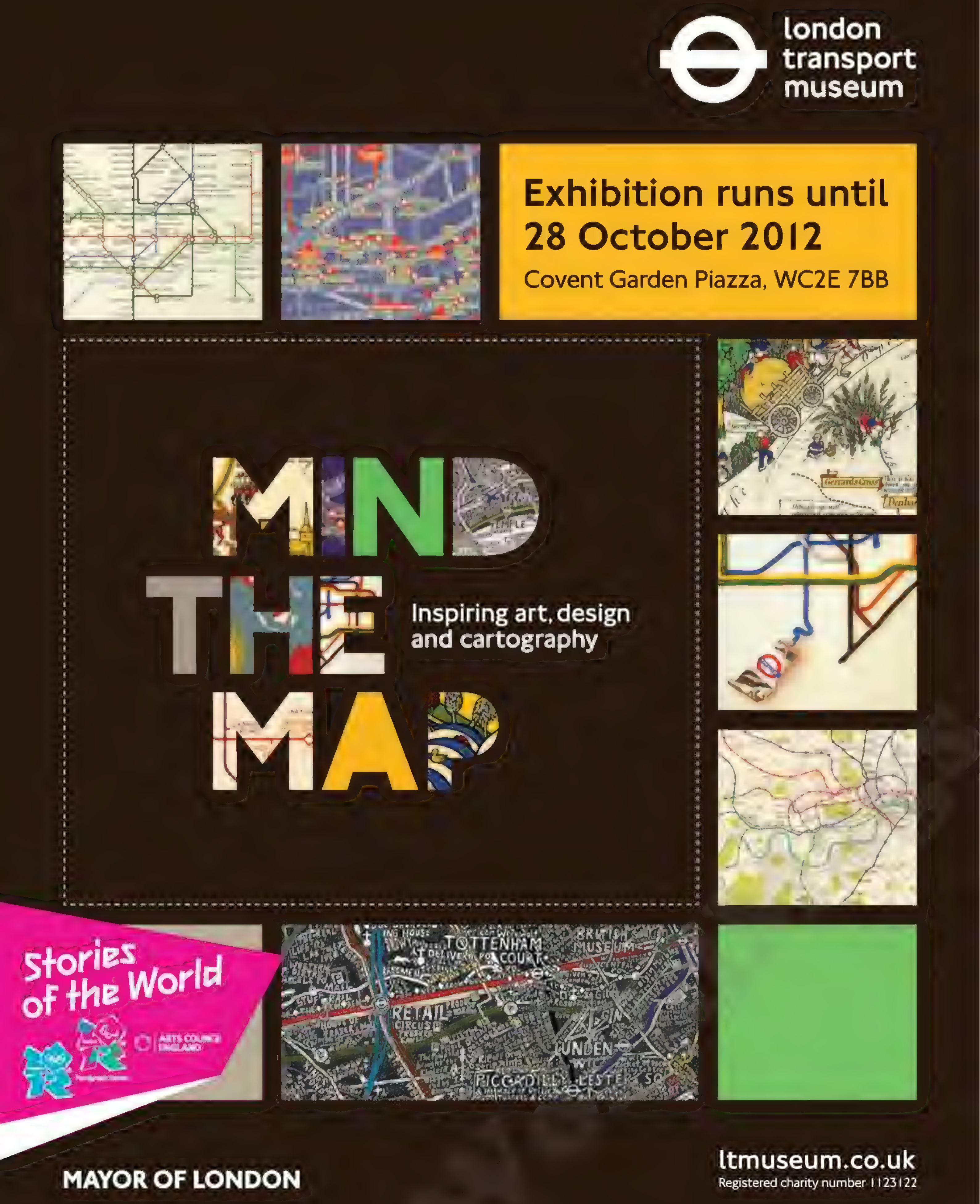
Top speed: >161km/h (>100mph)

Acceleration: 0-161km/h (0-100mph) in 4.92 seconds

Length: 68.6cm (27in)

Width: 30cm (11.8in)

5x © Traxxas


TOTTENHAM COURT
BRITISH MUSEUM
RETAIL CIRCUS
LUNDEN
PICCADILLY
LESTE
SQ
Gerrards Cross
Denham
TEMPLE

> "Turbines are the next natural technological evolution of the water wheel"

The key to hydroelectric power

HOW WATER TURBINES WORK

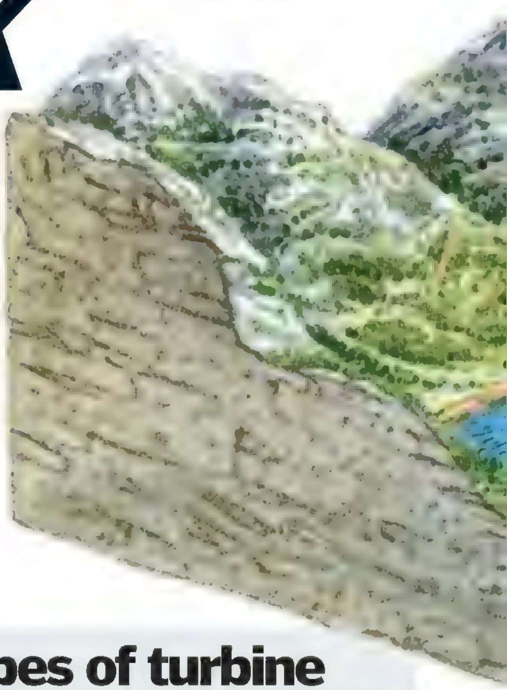
The simple technology that harnesses the immense natural power of water

Water wheels have been around for several thousand years, the concept of using water to power basic machinery like mill wheels (essentially harnessing the Earth's gravity) being well within the grasp of ancient engineers. Turbines are the next natural technological evolution of the water wheel and, although the Romans sometimes used a form of turbine for their water wheels and agricultural uses, it wasn't until the Industrial Revolution (circa 1750-1850) that the first modern turbines emerged.

Turbines are essentially propellers in reverse, both of which work in direct accordance to Isaac Newton's third law – namely, for every action there has to be an equal and opposite reaction. In propellers, that means energy is put into a spindle of asymmetrical blades that puts pressure on the air or water, which pushes back to propel the vehicle.

Turbines are usually fixed in place, so when a fluid flows through it there is a drop in pressure at the back edge of each blade that causes the turbine to turn. The principle is the same for air or water and the faster the medium is moving, the greater the pressure drop, and the faster the turbine spins.

It's a much more efficient method than water wheels that yields greater hydraulic head (ie the amount of force the water can generate) with smaller apparatus. Historically turbines directly drove the huge factories of the 19th century, but since the dawn of electricity, they're used to generate power that can be stored or passed on to the national electrical grid for a clean and renewable source of power.

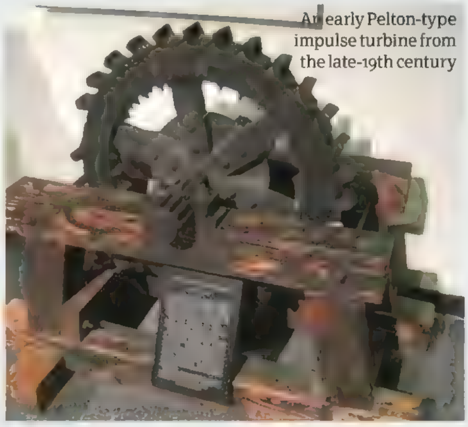


Source
Whether a lake or river, the source of water is chosen for its elevated position, from which the dam can take advantage of gravity.

The Hoover Dam is near Boulder City Nevada, USA. It impounds Lake Mead, [illegible] providing hydroelectric power since 1936

Types of turbine

There are two main types of turbine: impulse and reaction. Essentially these names describe the different blade mechanism used. In impulse turbines, where water jets onto the blades, the pressure drop (where the energy transfer occurs) takes place in the convergent guide vanes that direct the fluid onto the rotor blades. The opposite happens in a reaction turbine, where the rotor blades have convergent passages and the pressure drop happens here. Impulse turbines are usually unsuitable for low-head sites because they have low specific speeds, but they're easier to maintain. Reaction turbines, on the other hand, can rotate faster given the same head and flow conditions, but generally require a greater level of maintenance.



An early Pelton-type impulse turbine from the late-19th century

HEAD 2 HEAD
HYDROPOWER STATIONS

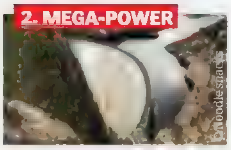
1. MICRO-POWER


© JDav

Trzebiatów Hydro Station

Micro-hydroelectric powerplants, like the 155kW Trzebiatów Hydro Station in Poland, can be a greener option than larger dams.

2. MEGA-POWER


© Noodle snac

Gordon Dam

The Gordon Dam in Tasmania has a 430MW capacity, making it something of a middleweight as far as hydroelectric dams go.

3. GIGA-POWER


© Yogho

Three Gorges Dam

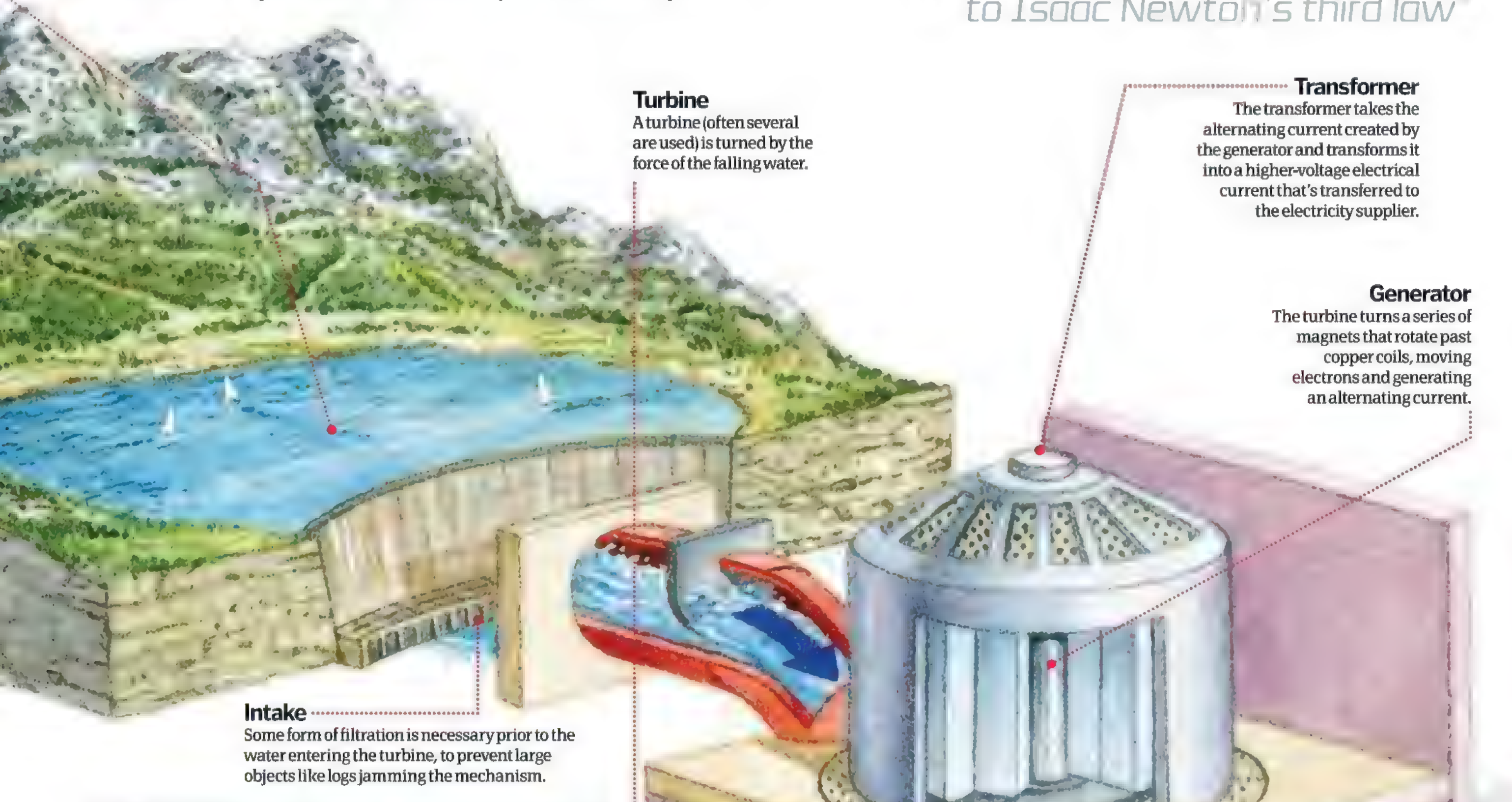
Easily the world's biggest hydroelectric powerplant is the Three Gorges Dam, which spans the Yangtze River in central Hubei, China. It can boast a staggering 18,200MW capacity.

DID YOU KNOW? *A prototype wind turbine in Abu Dhabi also creates 1,000l (265ga) of drinking water daily via condensation*

Turbines in context

A lake or river is dammed off and the natural elevation of the site is used to provide the source of the turbine's power

> "Turbines are essentially propellers in reverse, both of which work in direct accordance to Isaac Newton's third law"

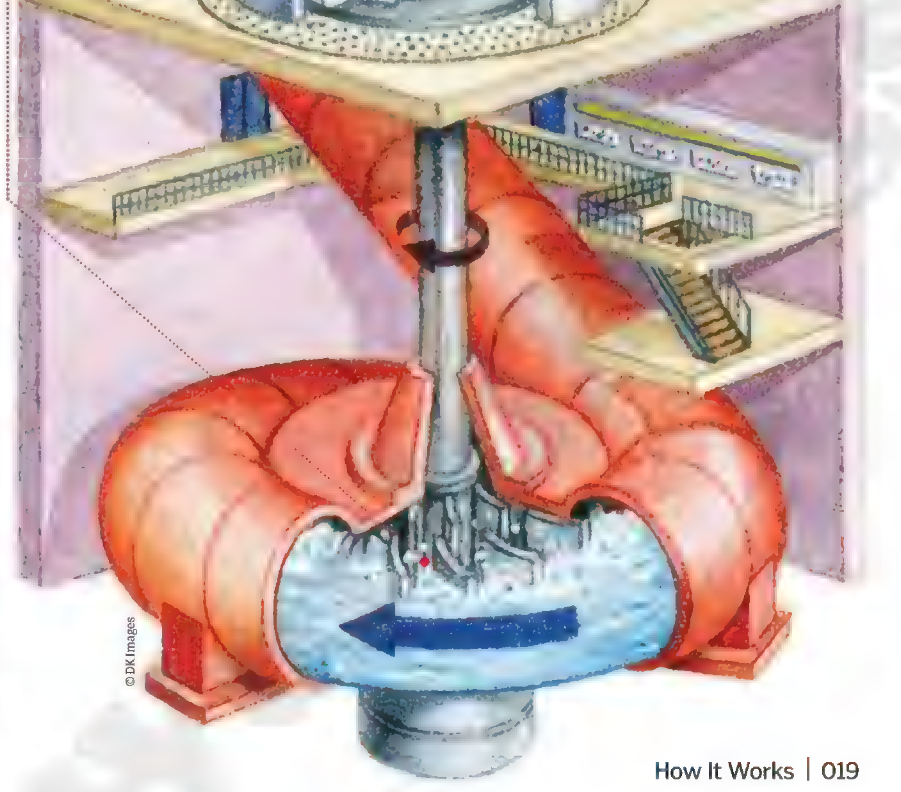


Turbine
A turbine (often several are used) is turned by the force of the falling water.

Transformer
The transformer takes the alternating current created by the generator and transforms it into a higher-voltage electrical current that's transferred to the electricity supplier.

Generator
The turbine turns a series of magnets that rotate past copper coils, moving electrons and generating an alternating current.

Intake
Some form of filtration is necessary prior to the water entering the turbine, to prevent large objects like logs jamming the mechanism.


© DK Images

How green is hydroelectricity?

As a direct source of energy, hydroelectric power by damming a moving body of water and releasing it via a turbine is environmentally friendly. There are no direct waste products and, as long as the water flows, it's an infinite source. But that doesn't mean hydroelectric dams are completely 'green'. Construction aside, a huge area of land is flooded to create the reservoir necessary to drive the turbines, which can upset local plant and animal ecosystems. While the turbine itself has no harmful emissions, the flooded area often drowns vegetation, which then decomposes anaerobically (without oxygen) underwater and produces methane, a greenhouse gas.


The Aswan High Dam protects Egyptian crops from Nile flooding, but the creation of Lake Nasser displaced 100,000 people

© Ingenieurlösungen

> "When launched it uses its radar altimeter to skim over the sea at a height of ten metres (33 feet)"

How an Exocet missile works

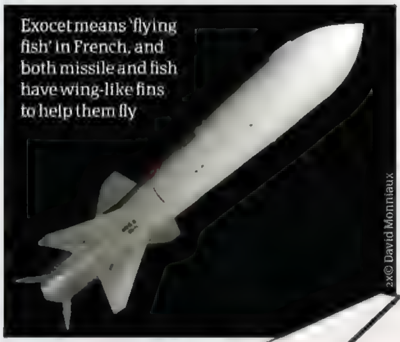
Discover the inner workings that, when combined, make up this notoriously deadly maritime weapon

The French-built Exocet MM38 began life back in 1967 as a surface-to-surface, ship-launched missile. In 1974 the air-to-surface Exocet AM39 was produced, and this was followed by the SM39 submarine-to-surface variant in 1979. Since its introduction, its inertial navigation system has been massively improved and it now contains a digital radar seeker to find its target, as well as systems to avoid electronic jamming.

When launched it uses its radar altimeter to skim over the sea at a height of ten metres (33 feet) and then descend to three metres (ten feet) as it closes in on its unfortunate target. On impact, the blast fragmentation warhead is capable of inflicting serious damage to huge warships such as destroyers and frigates.

Over 3,600 Exocets have been built and sold throughout the world since its inception. It proved a formidable weapon in the Eighties, when used in both the Falklands and the Iran-Iraq conflicts.

The latest MM40 Block 3 Exocet has a booster rocket and turbojet sustainer motor to reach a range of 180 kilometres (112 miles) and has a 3D navigation system with an active seeker capable of homing in on moving targets in complex situations from afar.

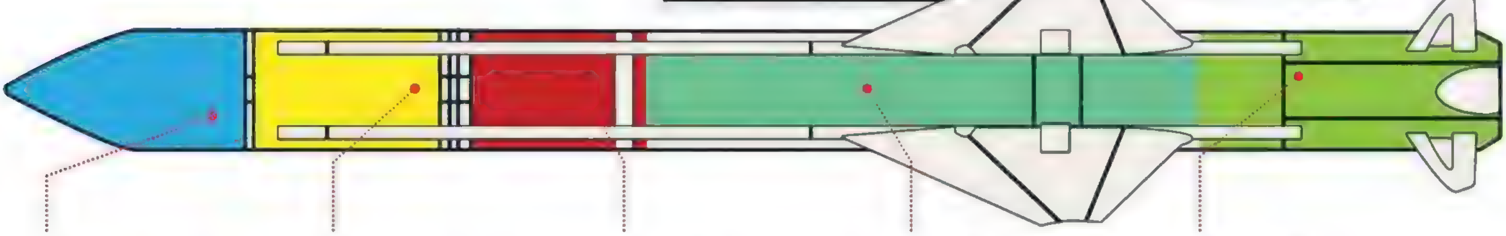


Exocet means 'flying fish' in French, and both missile and fish have wing-like fins to help them fly

2x© David Monniaux

Inside the AM39 Exocet

This air-to-surface missile can be launched from both fighter jets and medium-sized helicopters, but what lies within?



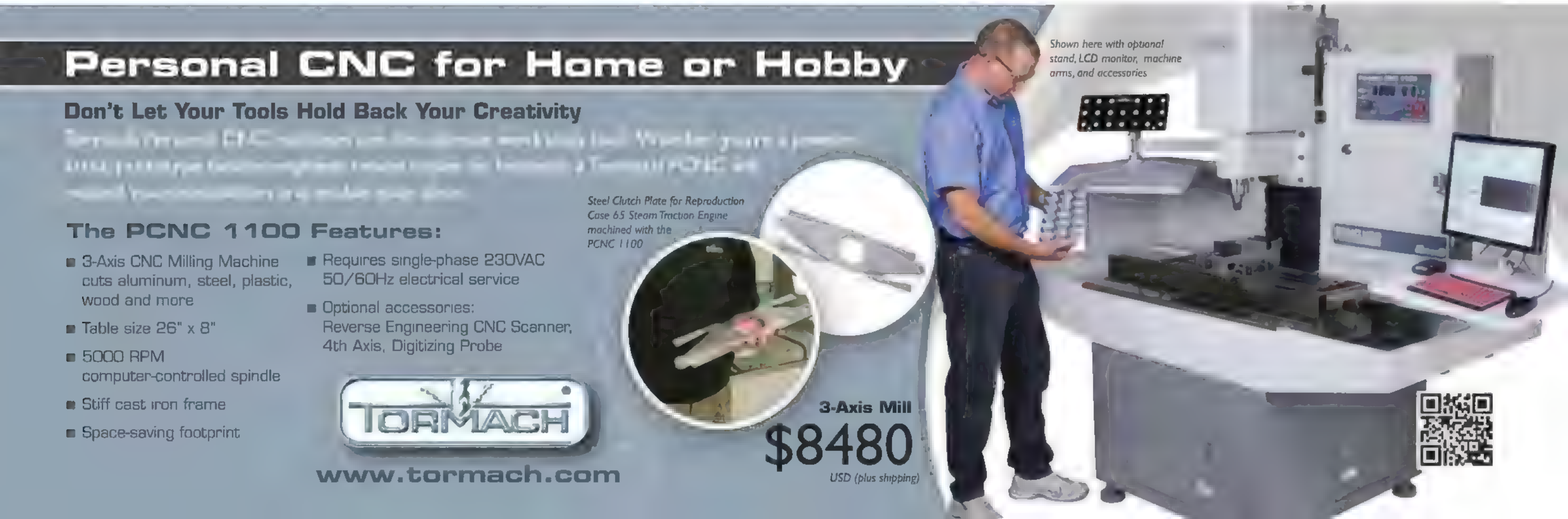
Seeker
The front of the missile houses the radar seeker equipment that includes an autopilot system, radio altimeter, accelerometers and gyros as part of its inertial navigation guidance systems and the radio proximity fuse.

Electronics
The distance and bearing of the target is inputted into the navigational computer before it is launched. Inertial guidance carries the missile to an activation point where the radar seeker actively searches for the target.

Warhead
All Exocet versions contain 165kg (363lb) of Hexolite explosive. A delayed fuse triggers the explosive once the missile has penetrated a ship's hull, though as a backup, a proximity fuse sets off the explosive if it overflies its mark.

Fuel tank
Contains a Condor solid-fuel booster rocket and a Helios solid-propellant sustainer rocket.

Powerplant
The booster rocket launches the Exocet to a speed of 1,138km/h (707mph), then its sustainer rocket motor fires for four minutes to maintain a speed of 1,116km/h (694mph). The AM39 missile has a range of up to 70km (44mi).



5 TOP FACTS RESPIRATORY TREATMENT

Breathe easy

1 Ancient cultures in India, Greece and Egypt discovered that inhaling the smoke or vapours from medicinal leaves and herbs helped relieve a number of respiratory problems.

Incense

2 Ancient civilisations also found that the smoke produced by burning incense (a mix of medicinal plants, minerals and gum resins) eased tension. It became common practice to use it to purify the air and during religious ceremonies.

Pressurised inhalers

3 These were invented by Riker Laboratories in 1956, after the daughter of the company's president asked why she could not use her asthma medication in the same way as her hairspray can worked.

Chlorofluorocarbons

4 In 2009, the US banned the use of CFCs as propellants in inhalers as they could be harmful to the ozone layer. Since then less harmful hydrofluorocarbons (HFCs) have been used instead.

Statistics

5 Over 5 million people in the UK suffer from asthma, and there are over 1,100 asthma-related deaths per year; 90 per cent of these are preventable with the correct use of an inhaler.

DID YOU KNOW? *Romans developed the original underfloor heating system over 2,000 years ago; it was called a hypocaust*

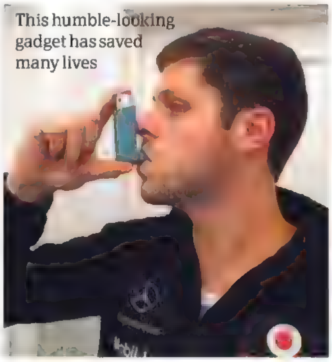
How do inhalers help asthmatics?

Why this portable device is something no asthma sufferer should be without

Metered-dose inhalers (MDIs) are small hand-operated devices that can send out an aerosol with a precise amount of medication into a small chamber. The user then breathes in the drugs through the mouthpiece, and the medication goes directly to the airways and lungs.

The inhaler, or puffer, consists of a plastic body and a pressurised canister that contains the medication and a propellant vapour. Large plastic, valved holding chambers, or spacers, can be fitted to the mouthpiece of the inhaler, if desired, so that the user has more time to inhale the aerosol.

For the treatment of asthma, the user usually has two colour-coded inhalers. One is a 'preventer' inhaler which contains medication that has to be used on a regular basis, and the other is a 'reliever'; the latter is used in the event of breathlessness or a sudden asthma attack.


This humble-looking gadget has saved many lives


Inside an asthma inhaler

Top of inhaler or canister
You push down on the top to press a spring into the canister, which delivers one dose of medicine.

Canister
The replaceable canister contains the drug mixture (commonly including anti-inflammatory steroids) and propellant vapour; it is held inside the actuator body of the inhaler

Metering chamber
This holds one dose of the medication; as soon as it is released, it is replaced by another dose

Actuator nozzle
This sprays out the drug-saturated vapour into the expansion chamber.

Mouthpiece
You breathe in the aerosol directly through the mouthpiece, or via a spacer attached to the mouthpiece.

© SPL

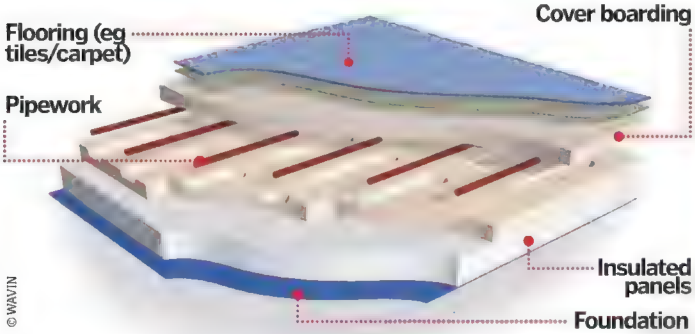
How underfloor heating works

What is this economical and efficient way of keeping our homes toasty?

Traditional wall-mounted radiator heating systems convect heat into the room, sending heat towards the ceiling in a circular cycle. In contrast, underfloor heating consists of electric elements, or water pipes, that radiate heat up evenly throughout the whole room. For optimum efficiency, a thermostat in each room can monitor and control the temperature.

Underfloor heating is also unobtrusive and easier to maintain as the elements, or pipework, can be embedded in concrete floors when houses are constructed, or they can be fitted under existing flooring.

A saving of 20 per cent can be made on fuel bills, and for buildings with high ceilings, savings can reach as high as 40 per cent compared with traditional heating systems.



© WAVIN

Why is eBanking safer with chip readers?

Get to know the chip authentication tech that makes online banking much more secure

Chip authentication readers use a two-factor chip authentication method, which consists of 'something you know', such as your PIN number or password, and 'something you own' such as your existing chip-enabled bankcard or a special authentication card.

When you insert your card into the handheld device and enter your PIN number, the reader generates a unique eight-digit code. This code number comprises a secret seed value that is permuted every time you enter your PIN number, or it is altered at specific time intervals. The host server recognises this number when you use it to log in to your online banking account. The reader is not physically connected to your computer and a new code has to be generated every time that you log in to your account.

> "A notable software inclusion is the next iteration of Samsung's voice-recognition app: S Voice"

Inside the Galaxy S III

What technology lies within Samsung's fastest-ever smartphone? Explore our teardown to find out…

The Galaxy S III is the latest iteration of Samsung's Galaxy series of smartphones. It runs on the cutting-edge version of the Android OS, Ice Cream Sandwich, and delivers a raft of new hardware and software.

In terms of hardware, the S III's arsenal includes a 1.4GHz, quad-core CPU, a 720 x 1,280 HD Super AMOLED capacitive touchscreen, 1GB of RAM, 16-64GB of storage space, an eight-megapixel rear camera, a 2,100mAh lithium-ion battery and a whole host of connectivity and motion sensors, including an accelerometer, gyro, Wi-Fi module and RF transceiver among others.

As far as the device's hardware specs go, a couple of elements of the S III stand out. The phone's Multi-Chip Package (MCP), for instance, allows the majority of its memory chips – regardless of type – to be integrated into a single bundle. As such, the S III's NAND flash, NOR flash and SDRAM/DRAM memory chips are all situated on the MCP; this enables the memory subsystem to view and access the chips as a single, unified block, granting incredibly high data transfer rates.

The other hardware element worth mentioning is the S III's 12.2-centimetre (4.8-inch), Gorilla Glass display. The screen adopts Samsung's HD Super AMOLED screen technology, which – thanks to the inclusion of two sub-pixels per every pixel on the display – allows the S III to generate great contrast ratios and clean colours. Bonded directly to the display is a piece of Corning Gorilla Glass, which is a form of alkali-aluminosilicate sheet glass that specialises in preventing scratches and cracks if the device is dropped. This is thanks to its ion exchange manufacturing process: the glass is bathed in molten potassium nitrate to force sodium ions to exchange with 30 per cent larger potassium ions in order to toughen up the material.

In terms of software, the S III has a couple of new additions that are integrated efficiently into Ice Cream Sandwich's host of stock OS features (for a rundown of these see the Galaxy Nexus article in issue 30 of **How It Works**). The first of these is Smart Stay, a piece of software that utilises the S III's front-mounted camera to continuously track your eyes and, as a consequence, ensure the display stays lit whenever a user is looking at it or dim/off if they are not. Testing revealed the feature worked roughly 80 per cent of the time. The other notable software inclusion is not entirely new but the next iteration of Samsung's voice-recognition app: S Voice. This is a Siri-like program that, through its use of a natural language user interface and various web services, such as Wolfram Alpha, allows basic commands and queries to be automatically responded to.

> "In terms of hardware, the S III's arsenal includes a 1.4GHz, quad-core CPU"

The Galaxy S III is only 8.6mm (0.34in) thick

© Samsung

The statistics…

Galaxy S III

Height: 136.6mm (5.38in)
Width: 70.6mm (2.78in)
Depth: 8.6mm (0.34in)
Weight: 133g (4.7oz)
OS: Android 4.0.4 (ICS)
CPU: ARM Cortex-A9 (1.4GHz)
RAM: 1GB
Storage: 16-64GB
Battery: 2,100mAh
Display: 12.2cm (4.8in) HD sAMOLED (1,280 x 720px)

Motherboard
The S III's motherboard holds a bounty of chips, including the device's quad-core A9 CPU and 16GB NAND flash memory.

Cameras
The Galaxy S III comes equipped with two cameras: a rear-facing 8MP camera and a front-facing one that features 1.9MP.

Case
The casing is made from brushed polycarbonate and can be removed easily by prying open a few tabs. It tapers at each end slightly to create a smooth bezel.

Battery
The 3.8V, 2,100mAh cell is a lithium-ion variety and incorporates the antenna necessary for near-field communication (NFC) features.

Screen
The 12.2cm (4.8in) display is fused to the Gorilla Glass and to the S III's polycarbonate frame. The screen can boast 306 pixels per inch.

© Chipworks/iFixit.com

Starting blocks

A far cry from the days when athletes had to dig their own starting holes

In 1932 Omega became the official timekeeper of the Olympic Games and, over the years, the company has introduced numerous state-of-the-art time-keeping technologies. Today's fully automated Olympic and Paralympic Games feature such precision engineering as high-speed cameras for capturing nail-biting photo finishes, touch-sensitive contact pads for timing swimming events, as well as plenty of innovative tech for starting races.

The 'Electronic Start System' involves a flashgun and sound-making device. With one pull of the trigger, a bang, a flash and a start pulse are all emitted at the same time. The start pulse is sent to the timing device, signalling the start of the race and commencing the precision data measurement. The competitors all 'see' the light flash from the gun at the same time, but to ensure that they all 'hear' the sound simultaneously too, the noise is reproduced from a mini speaker positioned behind each racer's starting block.

Omega's newest starting blocks measure the runner's reaction time not by movement but by the pressure they exert against the foot pad. No one's reaction time is faster than one tenth of a second, therefore if the sensors in a starting block detect that a runner has exerted any force on the pressure pads on the pedal, then they are deemed to have started too early and a false start will be confirmed.

Omega's athletics starting blocks

The tech behind 'on your marks, get set, go!'


© Omega

Pedals
The pedals offer the runner momentum when starting a race. In 2012 the foot pads have been enlarged from 120mm to 160mm (4.7in to 6.3in) to cater for individual start position preferences. The pedal surface is covered by a rubberised material in order to increase grip.

Speaker
At the tail end of each block is an electronic speaker linked to the starter pistol. When the pistol is fired to indicate the beginning of the race the sound is reproduced here.

Rack
This is the heavy aluminium bar with notches to adjust the position of the blocks. This year the bar is thinner – reduced to 50mm (2in) – again offering improved start position options.

Learn more

Families looking for fun ways to learn about the science of sport throughout the Olympic and Paralympic Games can visit INTECH Science Centre's new hands-on exhibition zone. It's full of exciting activities to help children understand things like how muscles work, how concentration helps you compete better, and how to 'bend it like Beckham'. For more information go to **www.intech-uk.com**.

Understanding fire sprinklers

A closer look at how these firefighting devices extinguish a blaze

Fire sprinkler systems are fed by pressurised water from the mains or by their own supply. This water is kept from being released by a plug inside the sprinkler head that will only be released when the temperature exceeds 68 degrees Celsius (155 degrees Fahrenheit). At this temperature, the tiny ampule that seals the plug mechanism will shatter to release a deluge of water in one to two minutes.

In more vulnerable environments, smaller-diameter ampules are used for a faster response time. Some sprinkler heads have spring-loaded plates soldered in place over the plug, and are activated when the solder melts. These are known as closed-type sprinklers, because once they are opened, they will spray water until their supply is cut. The on-off sprinkler, although activated in the same manner, features a heat-sensitive pilot valve that stops the discharge of water once the temperature has dropped.

Inside the sprinkler head

How does it detect fire and then put it out?

Water supply
The sprinkler head is typically fitted to a network of water pipes and other sprinkler heads that work independently of one another.

Plug
The ampule seals the plug to prevent water being released under normal circumstances.

Bubble
The ampule contains an air bubble that allows for the normal expansion of the glycerin-based liquid inside it.

Ampule
This vacuum-sealed ampule contains a liquid that, when heated, breaks the glass, unsealing the plug to release water into the room below.

Deflector plate
When water is released this plate deflects it downwards in a hemispherical pattern.

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* [illegible]

> "Cyclonic vacuums separate dust by exposing the dirt-filled air to large centrifugal forces"

How bagless vacuum cleaners work

The humble vacuum cleaner has undergone a serious makeover. Learn how these everyday devices keep our homes spic and span

Vacuum cleaners work in a variety of ways, each largely dependent on the type of suction and filtering methods adopted. However, within the modern vacuum cleaner market, three main systems dominate, each using differing suction, separation and filtering techniques and technology.

The first common type is the direct fan variety, which can either use a bag or canister for dust storage. Direct fan vacuums suck up dirt through a large impeller mounted close to the brushbar – the cylindrical brush typically located at the front-bottom of the appliance – or suction opening. The dirt is agitated, ie drawn, out of the carpet or other surface through the impeller and then deposited into the device's storage container, either directly or through a filter. These units are generally used for industrial cleaning purposes, as they generate a high-volume, low-energy consumption airflow, however due to their low suction power and basic filtering system, they're not so well suited to the domestic environment.

The second main type of vacuum is the cyclonic variety. These differ significantly from direct fan types, as instead of separating dust with a series of impellers and bag filters, they do so by exposing the dirt-filled air to large centrifugal (ie moving away from the centre) forces. This works by the cleaner sucking in airborne dust into a specialised collection vessel at a specific angle (at a tangent). This process forces the air to generate a fast-spinning vortex, which

Shell
The ball's outer shell is made from glass-reinforced polypropylene, which both provides protection for all internal components and aids smooth manoeuvring.

5 TOP FACTS VACUUM CLEANERS

Sweeper
1 The first vacuum cleaners were called carpet sweepers and relied on elaborate, bellows-based mechanisms to generate suction. They manually swept up dirt and dust with rotating brushes.

Dyson
2 Today the foremost name in the vacuum industry is Sir James Dyson, a British engineer famed for creating bagless vacuum cleaners. It took him 5,000 prototypes to perfect.

Roomba
3 A recent addition to the market is the iRobot Roomba series of robotic cleaners. These small, circular devices use a variety of sensors to periodically clean a user's home automatically.

Filtration
4 Vacuum cleaners can use a variety of methods to filter gathered dust, ranging from traditional material-capturing bags to water filters and cyclonic separation.

Suck-cess story
5 After Dyson perfected his bagless cleaner, every vacuum manufacturer rejected it. Dyson set up his own company and is now worth £2.69bn ($4.2bn), according to Forbes.

DID YOU KNOW? *The first vacuum cleaner was patented by US engineer Daniel Hess in 1860*

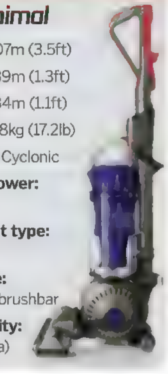
through its centrifugal force, causes the dust particles trapped within it to move to the outside of the vessel. The dirt, once freed from the air vortex, then falls to the base of the container through gravity for later disposal. In addition, due to the dust being separated without using a bag or extensive series of filters, cyclonic vacuums can boast very high suction levels. As such, they are very popular in residential markets, as their continuous high levels of suction enable various attachments for particular tasks to be used with little to no loss of airflow.

The third and most recent addition to the vacuum market is the robotic vacuum cleaner. These small – often circular – devices operate automatically by analysing a room with a variety of positional, acoustic and visual sensors and then proceed to periodically sweep its floor. These units typically use impellers, compressed vacuum bins and a series of filters to draw in fine particulate dirt through their bottom-mounted brooms and brushes, before storing it internally for later manual extraction. Due to the small-scale nature of these vacuum cleaners, they are commonly used for small residential or medical applications, however their suction volume and intensity matches neither direct fan nor cyclonic types and they do not generally accept attachments either which limits their usefulness.

Each of these three systems, as mentioned, uses one or more filters to remove particulate dust and dirt from the air, which all vacuums exhaust directly back into the immediate environment. These filters include standard bags, finely perforated paper or cloth containers, water tanks, plastic meshes, charcoal sheets and HEPA (high-efficiency particulate arresting) traps. Often, a combination of these filters is used within any given device, playing to each of their strengths. For example, charcoal sheets are especially good at removing odour particles, while HEPA traps specialise in capturing minuscule particles (as tiny as 0.3 micrometres).

The statistics…

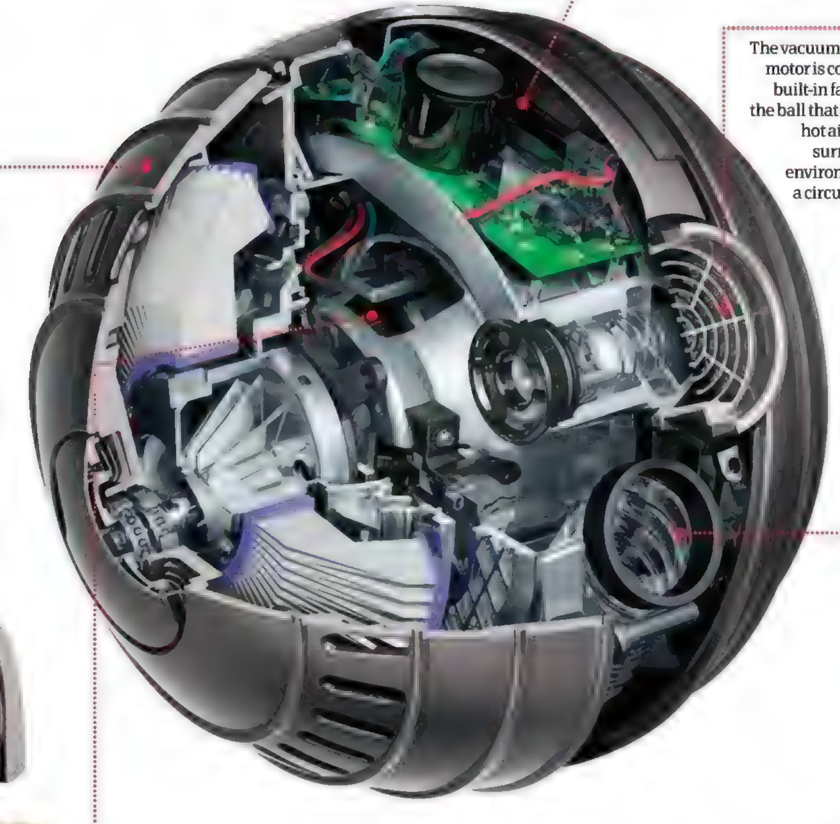
DC41 Animal



Height: 1.07m (3.5ft)
Width: 0.39m (1.3ft)
Depth: 0.34m (1.1ft)
Weight: 7.8kg (17.2lb)
Filtration: Cyclonic
Suction power: 255 AW
Movement type: Ball pivot
Head type: Motorised brushbar
Bin capacity: 2.1l (0.46ga)

Inside Dyson's DC41 Animal

The Dyson Ball is at the core of the DC41 vacuum, but what tech does this pivotable sphere conceal?



Cabling
The ball has also been designed to house the Animal's power cable, which extends into and out of a cavity near the motor.

Fan
The vacuum's electric motor is cooled by a built-in fan within the ball that transfers hot air into the surrounding environment via a circular series of vents.

Motor
A small electric motor lies at the heart of the ball and is used to power the fans, turbines and brushes of the DC41 Animal.

Ducts
Air drawn in through the brushbar and/or suction hose is routed through the ball itself through a series of ducts and into the bin.

Why is cyclonic cleaning so effective?

A landmark breakthrough in vacuum cleaner tech, cyclonic separation and filtration grants both power and efficiency

1 Intake
Dirt-containing air is routed into the collection vessel via the brushbar or suction hole and thrown against its outer wall at a tangential angle.

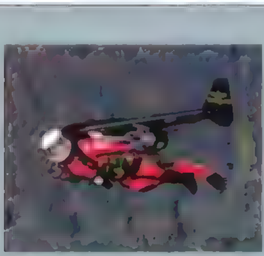
2 Vortex
A vortex is generated by the air's movement within the central bin, forcing large dirt particles and dust to be prised free and spun to the sides of the vessel.

3 Bin
The dirt, once free from the bin vortex, falls down the sides to the base of the container where it is stored. Typically, this bin can be manually removed by the user and simply tipped out with the general rubbish.

4 Filter
The remaining air – which may still be contaminated with fine dust – is then passed through an internal filter, trapping further dirt that may have been missed.

5 Mini-cyclones
Finally, the air is drawn up through the centre of the vacuum into a series of cyclones. Again the air is routed at a tangential angle, however their smaller size generates a higher velocity spin and allows even the smallest dirt particles to be captured, and again dropped into the bin below.

4x © Dyson



Welcome to…
TRANSPORT

[illegible]

LEARN MORE

How do manned submersibles safely descend to the deadly depths of the oceanic trenches?

EXTREME SUBMARINES

On 26 March 2012, Hollywood film director James Cameron ascended from the deepest part of the deepest oceanic rift in the world: the Mariana Trench, in the western Pacific. He wasn't the first person to reach the abyssal 11-kilometre (6.8-mile)-deep valley in its floor, the Challenger Deep, and the publicity around the event probably had as much to do with the fact that he is such a well-known celebrity as anything else.

Cameron was actually the third person to go there (after Don Walsh and Jacques Piccard's 1960 descent in the Bathyscaphe Trieste), but he was part of the second manned mission to the Challenger Deep and the first person to reach the bottom of the Mariana Trench solo. And to put all that into better perspective, NASA alone has sent 24 men to the Moon, 12 of them actually leaving their command modules and walking around on its surface, which would have been an impossible feat for this trio of intrepid aquanauts.

So what are the challenges posed by this geological giant, which could swallow Mount Everest and still leave over two kilometres (1.25 miles) of water above its highest peak? The single biggest obstacle for any submersible diving to these depths is the extreme pressure. Because seawater has more mass than air per volume – typically 1,025 kilograms per cubic metre (64 pounds per cubic foot) versus 1.23 kilograms per cubic metre (0.08 pounds per cubic foot), for roughly every ten metres (32 feet) you dive into the ocean, the pressure increases by one standard atmosphere (one bar). So the pressure near the bottom of the Challenger Deep exceeds 1,000 bars, or 1,000 kilograms per square centimetre (14,500 pounds per square inch), although temperature, tides and other factors mean this varies.

Naturally such extreme pressures would crush us to a pulp, so a manned submersible that visits the Challenger Deep needs to have enormous compressive strength to maintain the habitat inside it, while keeping its human occupants warm and supplying them with breathable air.

Cameron's Deepsea Challenger had a similar structure to the Bathyscaphe Trieste, though its torpedo shape was designed to descend lengthways. At one end is the pilot sphere, the only line of defence against a wall of deadly water. To minimise weight and increase strength, the interior is just 109 centimetres (43 inches) in diameter, while the hull is made of 6.4-centimetre (2.5-inch)-thick steel. The spherical shape of the chamber

THE STATS
DEEP-SEA EXPLORATION

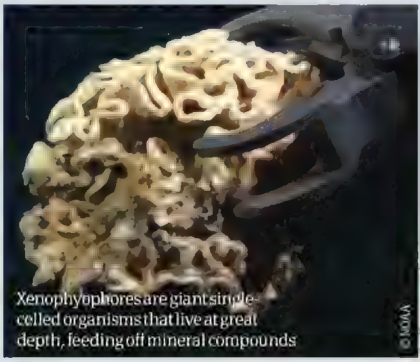
MARIANA TRENCH DISCOVERED 1876
MARIANA TRENCH AGE 170m years
MARIANA TRENCH FIRST EXPLORED 1960
VIRGIN SUB SPEED 3 knots
WEIGHT OF THE DEEPSEA CHALLENGER 11.8 tons
VIRGIN SUB COST $17m

DID YOU KNOW? *Most of Earth's ocean floors are 6,000m (19,685ft) deep, which is why subs tend to be rated only to this depth*

LIFE IN THE TRENCHES

We know very little about life in the deep ocean, but we do know that in the pitch black at the bottom, creatures can thrive. Microbes with the capacity to metabolise the hydrogen sulphide and other compounds that spout from boiling hydrothermal vents form the base of a food chain. In turn this attracts deep-ocean specialised crustaceans, gastropods, worms, eels and more in a place that was, up until the Sixties, thought to be uninhabitable. Incredibly, giant single-cell, amoebic organisms known as xenophyophores are found in their greatest numbers in the oceanic trenches.

Bottom-feeders in the dark regions of the ocean are usually scavengers, feeding off whatever falls from the waters above. But much of the taxa found in the extremes of the deep derive their energy from sources other than the Sun, in an environment that is analogous to those found on other planets in the Solar System. Indeed, extensive studies into these communities has breathed new hope into discovering life elsewhere in the cosmos.


Xenophyophores are giant single-celled organisms that live at great depth, feeding off mineral compounds

© NOAA

makes it much stronger; if it was cylindrical like the rest of the sub, it would need to be three times as thick.

To facilitate its descent, 450 kilograms (1,000 pounds) of steel weights are held on the side by electromagnets. These are dropped when the pilot needs to rise, but in case they don't (thereby marooning the submersible on the ocean floor), a power failure will drop the weights automatically, the support team on the surface can trigger the command themselves and, as a failsafe, a wire that helps connect the weights to the submersible will corrode and snap after 13 hours' exposure to seawater.

In any case, the Deepsea Challenger uses syntactic foam floats, dense enough to withstand the pressure yet lighter than water – these are able to rapidly lift the craft back to the surface in just half the time it took to reach the bottom.

The Deepsea Challenger

The essential difference between a submersible and a submarine is that a submarine must be able to recycle its own air and power supply, while a submersible relies on a support craft on the surface. This is why military submarines can go for months at sea, while both the Virgin Oceanic and Deepsea Challenger submersibles can only support their pilots for a day or so at most.

Thrusters
These control the altitude of the sub, suspending it above the ocean floor or propelling it downward.

Batteries
Hundreds of small lithium batteries that power the vessel absorb seawater to compensate for battery oil compression.

Cameras
The four bespoke HD cameras are a tenth of the size of cameras used in previous missions.

Pilot sphere
One pilot and all their equipment, as well as the craft's instruments, are crammed into a 109cm (43in)-wide space.

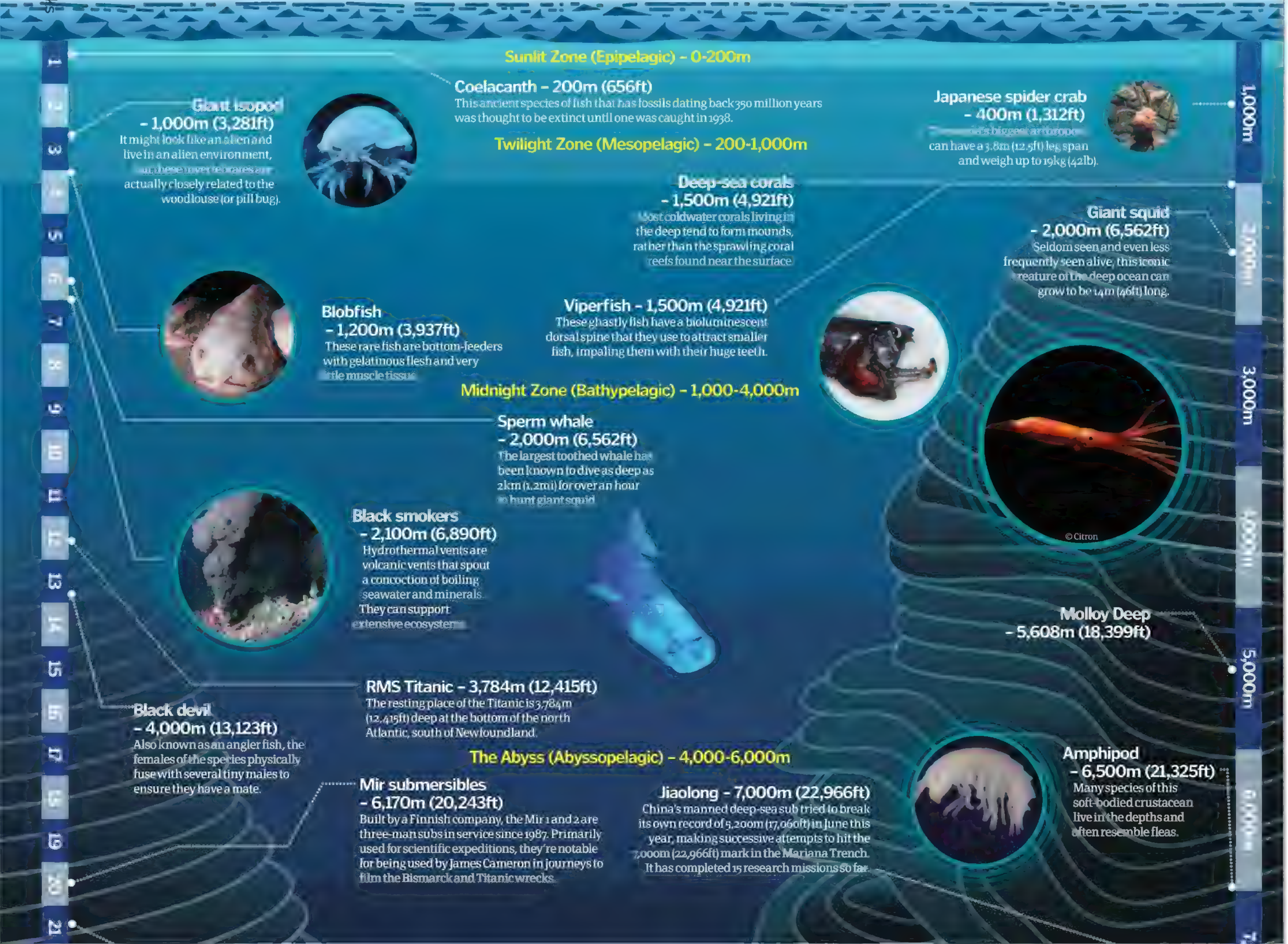
Air
The pilot sphere is supplied with up to 56 hours of oxygen, while excess carbon dioxide is scrubbed from the air.

> *"A manned submersible needs great compressive strength to maintain the habitat inside"*

"Hydrothermal vents are volcanic vents that spout a concoction of boiling seawater and minerals"

Taking the plunge

From the shallows to the murky depths, what can deep-sea subs expect to see on the way down?



Sunlit Zone (Epipelagic) - 0-200m

Coelacanth - 200m (656ft)
This ancient species of fish that has fossils dating back 350 million years was thought to be extinct until one was caught in 1938.

Japanese spider crab - 400m (1,312ft)
The world's biggest arthropod can have a 3.8m (12.5ft) leg span and weigh up to 19kg (42lb).

Twilight Zone (Mesopelagic) - 200-1,000m

Giant isopod - 1,000m (3,281ft)
It might look like an alien and live in an alien environment, but these invertebrates are actually closely related to the woodlouse (or pill bug).

Blobfish - 1,200m (3,937ft)
These rare fish are bottom-feeders with gelatinous flesh and very little muscle tissue.

Deep-sea corals - 1,500m (4,921ft)
Most coldwater corals living in the deep tend to form mounds, rather than the sprawling coral reefs found near the surface.

Viperfish - 1,500m (4,921ft)
These ghastly fish have a bioluminescent dorsal spine that they use to attract smaller fish, impaling them with their huge teeth.

Midnight Zone (Bathypelagic) - 1,000-4,000m

Giant squid - 2,000m (6,562ft)
Seldom seen and even less frequently seen alive, this iconic creature of the deep ocean can grow to be 14m (46ft) long.

Sperm whale - 2,000m (6,562ft)
The largest toothed whale has been known to dive as deep as 2km (1.2mi) for over an hour to hunt giant squid.

Black smokers - 2,100m (6,890ft)
Hydrothermal vents are volcanic vents that spout a concoction of boiling seawater and minerals. They can support extensive ecosystems.

RMS Titanic - 3,784m (12,415ft)
The resting place of the Titanic is 3,784m (12,415ft) deep at the bottom of the north Atlantic, south of Newfoundland.

Black devil - 4,000m (13,123ft)
Also known as an angler fish, the females of the species physically fuse with several tiny males to ensure they have a mate.

The Abyss (Abyssopelagic) - 4,000-6,000m

Molloy Deep - 5,608m (18,399ft)

Mir submersibles - 6,170m (20,243ft)
Built by a Finnish company, the Mir 1 and 2 are three-man subs in service since 1987. Primarily used for scientific expeditions, they're notable for being used by James Cameron in journeys to film the Bismarck and Titanic wrecks.

Amphipod - 6,500m (21,325ft)
Many species of this soft-bodied crustacean live in the depths and often resemble fleas.

Jiaolong - 7,000m (22,966ft)
China's manned deep-sea sub tried to break its own record of 5,200m (17,060ft) in June this year, making successive attempts to hit the 7,000m (22,966ft) mark in the Mariana Trench. It has completed 15 research missions so far.

RECORD BREAKERS
EARLIEST SUB

1620

WORLD'S FIRST SUBMERSIBLE

The world's first proven submersible was designed by William Bourne and built by Cornelius Drebbel in the early-17th century (circa 1620). It was propelled a few feet underwater by oars.

[illegible] Because of the immense pressure, water doesn't boil in black smokers until it reaches up to 400°C (752°F)

Shinkai 6500 – 6,500m (21,325ft)
This Japanese submersible is rated to dive deeper than any other manned research vessel and, unlike the Bathyscaphe Trieste and the Deepsea Challenger, it's capable of navigating along the bottom. It's clocked 1,300 dives since 1991 and had major upgrades to its systems in March this year.

Snailfish – 8,368m (27,454ft)
This species was the deepest fish ever caught in 1970 at 8,368m (27,454ft) at the bottom of the Puerto Rico Trench.

The Trenches (Hadalpelagic) – 6,000-11,000m

South Sandwich Trench – 7,235m (23,736ft)

Diamantina Trench – 8,047m (26,401ft)

Puerto Rico Trench – 8,605m (28,232ft)

Mariana Trench – 11,034m (36,201ft)

Deepsea Challenger – 10,912m (33,438ft)
James Cameron's bathyscaphe sub broke a 50-year-old record by reaching a depth of nearly 11,000m (36,09?ft)

ON THE MAP

Deep oceanic trenches
1 Mariana, West Pacific
2 Puerto Rico, Caribbean
3 Diamantina, Indian Ocean
4 South Sandwich, Southern Ocean
5 Molloy Deep, Arctic Ocean

Unless credited otherwise, all images © NOAA

VIRGIN OCEANIC

Virgin Oceanic plans to launch an even more ambitious craft into the Mariana Trench. It too will be a one-man submersible but made of 3,630 kilograms (over 8,000 pounds) of carbon fibre and titanium. It's supported from the surface by the Virgin Oceanic Super Catamaran, adapted from Steven Fossett's racing catamaran, the Cheyenne. Virgin Oceanic's version is a gigantic 38.1 metres (125 feet) long and 48.7 metres (160 feet) to the tip of its mast. It can lower the sub into the water through a hole in the deck of one hull, while the other hull serves as a galley for the 12-man crew.

The sub is designed to incorporate hydroplanes (aquatic wings) that will allow it to move across up to ten kilometres (6.2 miles) of ocean floor, with a large quartz viewing dome capable of withstanding nearly 6 million kilograms (13 million pounds) of pressure. On its own dive into the Mariana Trench later in 2012, this vessel will be piloted by someone equally as famous as James Cameron: Sir Richard Branson.

© Virgin Oceanic

> "Once the rubbish is within the refuse hold, it is often exposed to a shaking unit"

The clean machine

Check out this cutaway to see how road sweepers gather and filter rubbish

© Elgin Sweeper Company

Refuse hold
The refuse hold is substantial and is equipped with a shaker to loosen particulate dust and debris from rubbish for processing by the sweeper's filtration system.

Filtering system
A series of fans, meshes, vibrators and hoppers designed to separate and trap fine dust, which is a primary source of water pollution. Filtered air is then expelled back into the atmosphere.

Brooms
Metal wire brooms surrounded by vacuumised chambers help draw rubbish to the side of the sweeper into the mid-centre of the vehicle, where it's drawn up into the refuse hold.

Escalator
The escalator carries the gathered litter upwards to the top-rear of the refuse hold, where it is deposited for later extraction and processing.

Roller brush
The rear tubular roller brush gathers up large-scale refuse and deposits it onto a central elevator. It is surrounded by a vacuumised chamber that sucks up finer particulate dirt.

Mechanised street sweepers explained

Discover how these vehicles pick up and process rubbish, with the aim of keeping our roads clean

Mechanical street sweepers today are usually large cab-over trucks equipped with a specialised cleaning module. These modules tidy up our roads using a series of rollers, brooms, sprays, filters and vacuums, combining these tools to quickly gather physical litter and process particulate dirt.

The two main types of sweeper are characterised as wet and dry units, the former installed with a large water tank and sprayers to help loosen caked-in grime, and the latter relying solely on a set of rollers and brushes. Key to both variants, however, is a series of vacuumised chambers that surround the vehicles' litter collection units.

These vacuums – commonly positioned around a sweeper's rear roller brush and side-mounted brooms – draw both rubbish and fine particulate matter into a refuse hold and filtering system, supporting the physical gatherers. This action can be likened to that of an everyday household vacuum cleaner.

Once the rubbish is within the refuse hold, it is often exposed to a shaking unit, which separates further debris particles. These are sent, along with directly sucked-up dirt, into a filtering system. At this stage, a series of fans, filters and hoppers extracts the dust from the internal dirty air, traps and stores it for later disposal, and then expels the processed clean air back out into the environment.

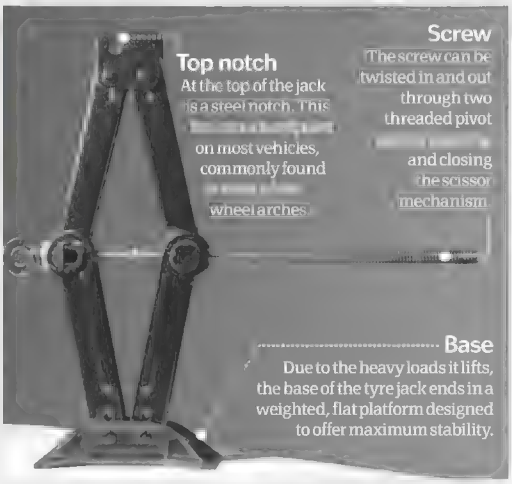
How do scissor jacks lift cars?

How these humble-looking devices prop up heavy vehicles

There are two main kinds of car jack: those operated by screw and those operated by hydraulics. For standard road vehicles, the screw type is most common, often coming in the form of a scissor jack. Their popularity is a result of their ability to generate a great mechanical advantage – ie a large force amplification – from a manually operated arm tool.

These jacks work by using a two-piece mechanism – similar to those found on extending bathroom mirrors – in partnership with a self-locking central screw. Combined, these elements not only enable a vehicle to be lifted through the extension of the scissor mechanism, but also to be held in place by the resistive force of the screw, which without the jack would instantly collapse.

The central screw is also how the jack is operated, with an end-mounted circular ring designed to accept a large Allen key-shaped metal arm. When inserted and turned clockwise this arm drives the screw through the scissor mechanism's central pivot points' thread, elongating the jack and, thus, raising the vehicle. In contrast, rotating the screw counter-clockwise unthreads the screw, shortening the jack and, in turn, lowering the car to the ground.



Top notch
At the top of the jack is a steel notch. This [illegible] on most vehicles, commonly found [illegible] wheel arches.

Screw
The screw can be twisted in and out through two threaded pivot [illegible] and closing the scissor mechanism.

Base
Due to the heavy loads it lifts, the base of the tyre jack ends in a weighted, flat platform designed to offer maximum stability.

> "The WaveJet Pod works by drawing water into a pair of aluminium impellers via two metal grilles"

What is engine oil?

What exactly does this lubricant consist of and why can't most vehicles function without it?

Engine, or motor, oil is designed to lubricate the inner components of internal combustion engines, as well as to protect them against corrosion and keep them cool while in use.

It's made from two main elements: base stock and additives. The base stock commonly makes up 95 per cent of the solution and is either made from petroleum, synthetic chemicals or a mixture of the two. The base stock is responsible for lubricating an engine's moving parts and removing built-up heat. The additives, meanwhile, account for roughly five per cent of the oil and it is these chemicals that are responsible for finely controlling oil viscosity and lubricity, as well as protecting engine parts against wear. For example, zinc dialkyldithiophosphate (ZDDP) is a frequently used additive for preventing wear, while magnesium sulphonates help the oil to break down impurities and engine sludge.

Engine oils are rated by their grade and viscosity. Any oil can either be single-grade, with a set viscosity level, or multi-grade in which the oil can act at two different viscosities depending on its temperature. The latter is most prevalent today, to cater for vehicles used all year round in various conditions. The flow-rate of both single- and multi-grade oils is measured on a viscosity grade scale, which includes 11 grades ranging from 0 to 60. Lower-ranked oils are thicker than higher-ranked ones, making them more suitable to cold environments, and vice versa.

Multi-grade oils have a base viscosity grade when cold, and a second grade for when hot

A piston-type dump valve as commonly used in motorsport vehicles

© Allison

Dump valves explained

How do these car parts help to relieve the strain in an engine?

A dump valve is designed to release unwanted pressure in a turbocharged car engine – pressure that, if left unchecked, would quickly cause great damage. The valve itself resembles a metallic tubular drum and can usually be found between the intercooler and the air inlet hose to a turbocharger.

How the system works depends on the kind of dump valve, but both types seek to negate the effect of compressor surge, a process where the action of the throttle plate closing on a turbocharged engine causes the high-pressure air within the intake system to be blocked and also forced back into the compressor. The first type of valve, known as a compressor bypass valve (CBV), is an engine manifold, vacuum-driven device that releases unwanted pressure in the engine's intake system before rerouting it via a hose back to the non-pressurised end of the intake for reuse. These are common in motorsport vehicles.

In contrast, the second type of dump valve, a blow-off valve (BOV), releases the pressurised air via a vent directly into the atmosphere with a loud popping/hissing noise. This type is more frequently used in road vehicles.

Jet-powered surfboards

How do these surfing systems generate extra thrust for prolonged wave riding?

Jet surfboards are surfboards with an integrated propulsion unit, a system designed to minimise the burden of paddling. The foremost example of these systems today is the WaveJet Pod, an oval-shaped thrust generator that comes pre-installed into a range of surfboards – however, it can also be integrated into standard boards. Once installed, this device allows surfers to travel at over four times the speed of manual paddling.

The WaveJet Pod works by drawing water into a pair of aluminium impellers via two metal grilles. The impellers, powered by the Pod's internal lithium-ion battery and controlled by the user with a wrist-mounted command centre, then draw the water through their blades and eject it via rear-mounted vents. This process generates roughly nine kilograms-force (20 pounds-force) of thrust – the equivalent to 11.3 kilometres (seven miles) per hour in speed.

The system is recharged by connecting it to a dedicated device, which comes in a watertight briefcase and can fully replenish the Pod in under four hours.

The WaveJet Pod in context

How this souped-up board can offer surfers a boost

Charging
The Pod's lithium-ion battery is charged via this watertight port.

Materials
The board is made from epoxy resin with an EPS core for lightness and durability. The addition of the WaveJet Pod adds both power and stability while riding.

Grilles
Water is drawn into the Pod through these metal grilles.

Jet vents
Lightweight aluminium impellers generate 9kgf (20lbf) of thrust, pushing water out of these two rear vents.

Release
The Pod is removed/secured to the board via a key tool connector at this point.

© WaveJet

STOP FACTS
JETMAN TRIVIA

Top gun

1 Yves Rossy is an ex-military fighter pilot who flew in the Swiss Air Force. His career saw him fly a number of combat aircraft including Mirage IIIs, F-5 Tiger IIs and Hawker Hunters.

Crossing the Alps

2 In 2008 Rossy flew his wing over the Swiss Alps mountain range. During his flight he reached a top descent speed of 304km/h (189mph) and an average speed of 200km/h (124mph).

The rain in Spain…

3 In 2009 Rossy tried to cross the Strait of Gibraltar, hoping to be the first person to fly between two continents using a jetwing. Unfortunately, bad weather meant he couldn't land in Spain.

Swiss Army strife

4 While only a rumour, it has been claimed that the Swiss military was so impressed with the jet-powered wing they asked Rossy to share a prototype. However, Jetman refused.

Jetwing vs rally car

5 One of Jetman's most recent outings was on the BBC motoring show *Top Gear*. Here Rossy piloted his latest jetwing in a race between him and a pro driver in a rally car.

DID YOU KNOW? *Swiss pilot Yves Rossy is the only person in history to fly with a jetwing*

Jetman's jet-propelled wing explained

We break down Yves Rossy's jet-powered personal flying machine that enables him to soar at nearly 200mph

Jetman, aka pilot Yves Rossy, is the world record holder for jet-propelled wing flight, successfully performing a series of jaw-dropping flights at speeds of up to 304 kilometres (189 miles) per hour.

He achieves these feats with his jet-propelled wing, a personal jetpack-style flying machine that is attached to Rossy much like a backpack, via a multi-point harness. The wing is powered by four small-scale jet engines, which are scaled-down replicas of those found on fighter aircraft. The engines burn a kerosene/turbine oil mix and each generates a modest 22 kilograms-force (48.5 pounds-force) of thrust – enough to enable Jetman to sustain low-altitude flight for 10-20 minutes depending on his speed and atmospheric conditions.

The wing itself is made from a series of carbon-fibre panels, which are bolted together to form a two-metre (6.6-foot)-wide main body. Attached to this are the wing's four jet engines as well as the fuel tanks, which sit either side of Rossy who is positioned at the top-centre of the aircraft.

Due to the large power and heat generated by the wing's engines, Rossy himself must wear a specially designed wing-suit when piloting it. This suit is designed to be heavily heat resistant and works in partnership with a carbon-fibre heat shield installed around the vehicle's exhaust tail.

The jetwing is controlled by a combination of Jetman's own head, arm and leg movements, and an engine throttle. Together, these enable Rossy to climb, descend and sweep left and right gracefully, without spinning out of control. However, in the event that a mechanical failure or other emergency were to occur, the wing can be detached and both Rossy and the device can land safely using parachutes.

The statistics…

Jetman's jet-powered wing

Span: 2m (6.6ft)

Weight: 55kg (121lb)

Powerplant: 4 x Jet-Cat P200

Fuel: Kerosene

Ascent speed: 180km/h (111mph)

Cruise speed: 200km/h (124mph)

Descent speed: 304km/h (189mph)

Canopy: PD Spectra 230

Parachute: Legend R

Parachutes
For landings or emergencies, two parachutes are installed in the body of the wing and on Rossy himself, which can be deployed manually or automatically.

Body
The wing's body is made from a number of carbon-fibre panels. Rossy can change direction through a series of body movements.

Engines
An array of four Jet-Cat P200 jet engines deliver 22kgf (48.5lbf) of thrust each, granting cruise speeds of 200km/h (124mph).

Harness
The harness, which holds the wing tightly to Rossy's back, is equipped with a cutaway system plus an automatic engine shut-down mechanism.

Fuel
The machine's engines run primarily on kerosene. However, a small quantity (approximately five per cent) of turbine oil is added to provide lubrication.

"The wing itself is made from a series of carbon-fibre panels"

© Yves Rossy, Andre Bernet

> "A bulldozer consists of many parts, but the main three are its blade, tracks and ripper"

Brutal bulldozers

Designed to move or demolish all in their path, these powerful vehicles are used by builders, farmers and even soldiers

Key to how a bulldozer operates is its large powerful engine and tracks, which combined allow the machine to push, pull and carry many-ton loads day in, day out. This is because the tracks generate excellent ground hold and weight distribution, preventing the bulldozer from becoming stuck or slipping on difficult terrain. This ability, in partnership with the vast amount of torque generated by the vehicle's diesel engine and torque divider, allows substantial loads to be manipulated with ease – indeed, modern bulldozers can pull tanks that weigh over 70 tons!

A bulldozer consists of many parts, but the three most noteworthy are its blade, tracks and ripper. Affixed to the front of the vehicle by a push frame, the blade is the heavy metal plate that's used to push objects and scoop up large quantities of material such as sand and earth. This element is usually one of three designs: an S blade, which is short and has no lateral curve and side wings; a U blade, which is tall and very curved with pronounced side wings that can gather more material; or an S-U blade, which is a combination of the other two types.

The tracks of a bulldozer also come in a variety of designs, though oval and triangle arrays are most common. A popular track system today is Caterpillar's triangular high-drive system, which is designed to generate a higher cab position for the driver – granting them better visibility during operation. This configuration also enhances the vehicle's balance and traction across all applications. For example, high-drive bulldozers deliver equal amounts of stability and grip no matter whether they are pushing, pulling or carrying their colossal loads.

The last key part is the bulldozer's ripper. This is a tool attached to the rear of the vehicle that's powered by a hydraulic cylinder. The ripper usually resembles a toothed blade – or series of toothed blades – and is used to break up hard ground so it can be scooped up or pushed by the blade. Rippers are designed with replaceable tungsten steel alloy tips to ensure they remain razor sharp. In addition, rippers can be modified to perform other tasks. A case in point are stump-buster rippers, which are sharp, horizontally mounted rear blades used specifically to split and shred tree stumps.

Due to their extreme power and performance, bulldozers have increasingly been called into military service, if greatly adapted for warzones. Modifications include armour plating, blast shields, bulletproof cab glass, machine guns and enhanced communication systems with GPS. A good example is the Caterpillar D9R (nicknamed Doobi – Hebrew for 'teddy bear'), which has been used by the Israel Defense Forces (IDF) for several decades.

Bulldozer breakdown

How It Works takes a closer look at the key components of a modern bulldozer

Ripper
A sharp metal-toothed feature that is driven into the ground by a hydraulic cylinder in order to break it up for easier excavation.

Push frame
A lengthwise connector between the bulldozer's frame and blade. It ensures the blade remains rigidly fixed during operation.

5 TOP FACTS
BULLDOZERS

Crawler

1 The term bulldozer was originally an engineering term to describe a horizontal forging press. It was not until the Thirties that the name was linked to the modern-day crawler vehicle.

Tractor roots

2 The first bulldozers were not purpose built but modified farm tractors. In the Twenties, however, purpose-built machines with tracks started to be manufactured and sold.

Caterpillar

3 The largest manufacturer of bulldozers is US company Caterpillar. Competitors include Komatsu, JCB and John Deere, which all produce vehicles of various sizes and specifications.

Calfdozer

4 While the majority of bulldozers are massive, more compact variants are produced for urban use where space is limited. These miniature versions are often called calfdozers.

Battle bulldozer

5 The most famous example of a military bulldozer is the Israel Defense Forces' Caterpillar D9R, named Doobi. This machine has been rigged out to demolish structures while under fire.

DID YOU KNOW? *In the early-Thirties bulldozers were commonly referred to as bull graders*

Cab

The command centre of the vehicle, the cab is the area where the driver sits and controls its movement, blade and ripper device.

Exhaust pipe

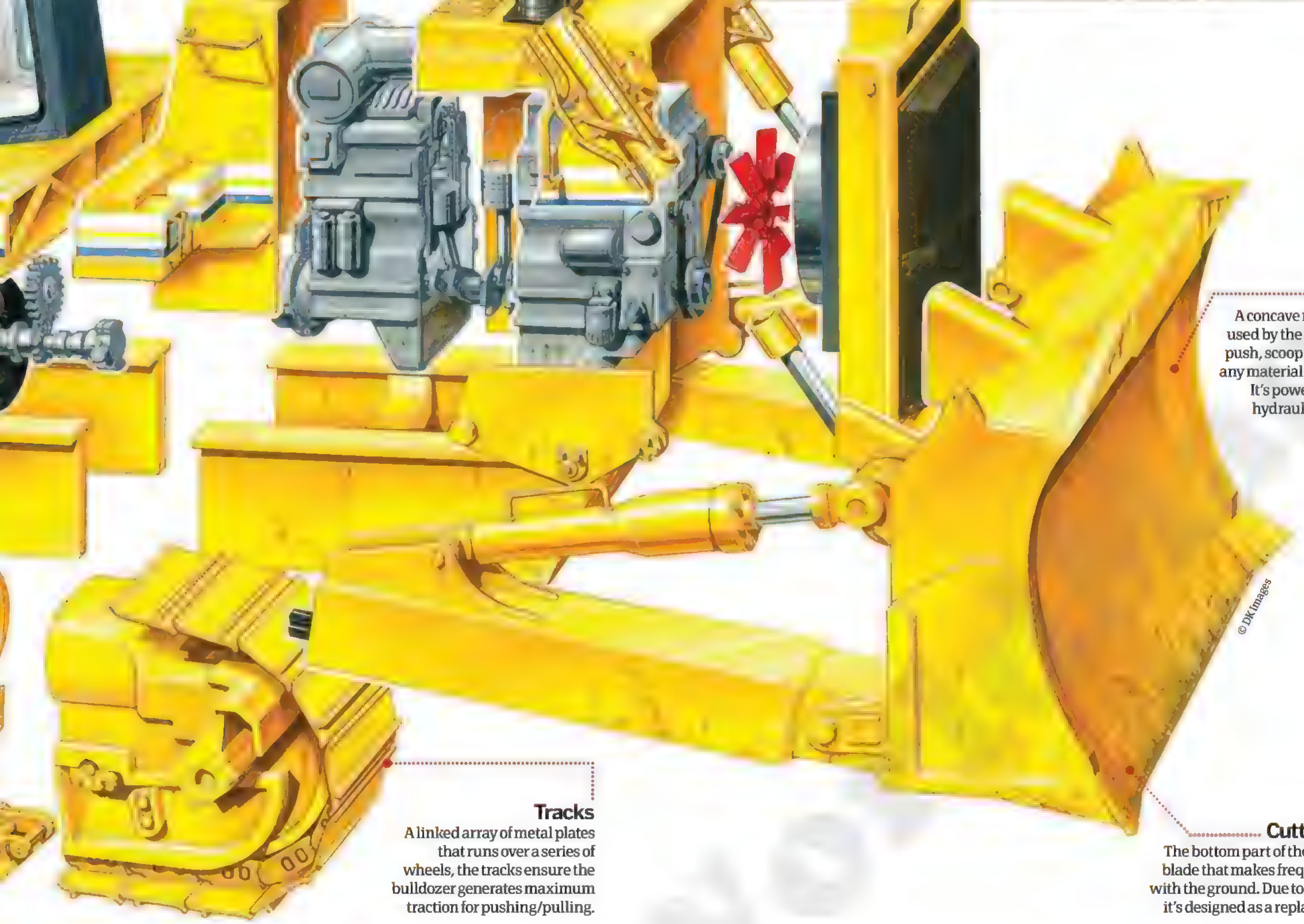
A large exhaust pipe through which the bulldozer's diesel engine can expel combustion gases.

The D11T is a mechanical monster, mainly used for shifting rubble/dirt etc within relatively confined areas

© Shaun Greiner

Lift cylinder

One of two hydraulic lifting cylinders that allow the blade to lift vast quantities of excavated material.



© DK Images

Blade

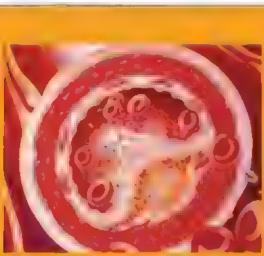
A concave metal shield used by the bulldozer to push, scoop and destroy any material in front of it. It's powered by twin hydraulic cylinders.

Tracks

A linked array of metal plates that runs over a series of wheels, the tracks ensure the bulldozer generates maximum traction for pushing/pulling.

Cutting edge

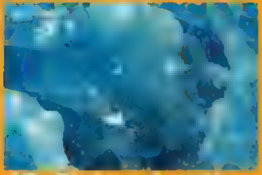
The bottom part of the bulldozer's blade that makes frequent contact with the ground. Due to heavy wear, it's designed as a replaceable part.



Welcome to... SCIENCE

[illegible] something – but how does fear rule our bodies? Also, learn how sound waves alone can lift objects, why natural rubber is toughened for tyres, and how scans can reveal our thoughts.

42 Tattoo removal



45 States of matter

46 Mind reading

LEARN MORE

THE SCIENCE OF FEAR

If your body is a vessel, fear is an all-hands-on-deck red alert

At the first sign of danger, your inner Kirk arms photon torpedoes, [illegible] shields and [illegible] battle stations – so to speak. [illegible] heightened alert as a racing heart, a surge of energy and a twisting stomach. In the right circumstances – on rollercoasters etc – the feeling can be a rush, but it's generally a distinctly unpleasant experience. So why do our brains subject us to it?

Simply put, fear keeps us alive. While [illegible] system might make public [illegible], it would also make you easy prey. When scientists liberated rats of their brains' fear centre, the subjects happily snuggled up to cats. In the unpredictable, predator-filled world of our ancestors (both human and pre-human), fear – a hair-trigger system that equips you to avoid, fight or flee danger – was essential to surviving long enough to make terrified babies that would carry on your genetic material. In other words, natural selection has assured that we and [illegible] other animal are primed to be afraid, in some form or another. More specifically, we're primed to be afraid *fast*. You might be [illegible] logically deduce that you should run from a charging rhinoceros, but when a rhino's actually barrelling towards you, there's no time for logic. That's why your fear system doesn't wait around for you to register what's going on consciously.

When something unexpected happens – a sudden bang, for instance – the information initially goes to your amygdalae, twin almond-shaped lobes near your ears that are critical to developing emotions. The amygdala associates certain sights, sounds and smells with danger. If it receives information that fits the profile of one of these dangers – a coiled creature on the ground, for example – the amygdala instructs your hypothalamus to trigger the fight-or-flight response to prepare your body to deal with the threat. Through your central nervous system and bloodstream, your

Heart rate rises
The heart beats faster and boosts the force of contraction, which increases the rate of [illegible] muscles.

Liver secretes glucose
Adrenaline triggers the liver to convert glycogen into glucose, the body's energy supply. This energy is then made readily available to [illegible].

Adrenal gland produces hormones (not shown)
The adrenal medulla, within the adrenal gland on top of the kidney, releases the hormones adrenaline (epinephrine) and noradrenaline (norepinephrine), which prod organs and muscles into action or inaction, respectively.

Kidney slows urine production (not shown)
Producing bodily waste is deemed an unnecessary drain on energy.

Intestines slow down digestion of food
In extreme cases, the body will clear the digestive tract altogether, through vomiting or defecation.

Bladder sphincter tightens
The bladder relaxes and the sphincter tightens as part of shutting off unnecessary systems.

5 TOP FACTS HUMAN FEAR

Superhuman

1 Normally, you can tap into about 65 per cent of the available energy in your muscles. Fear unlocks the deficit, enabling people in emergencies to often perform inexplicable feats.

Neurosis

2 One theory from a study at Tel Aviv University, Israel, is that people who have subpar danger-detection abilities overcompensate by being generally fearful/anxious.

Fearless mum

3 A 40-something mum known as SM lost her amygdalae to a degenerative disease. With no sense of fear, she readily approaches muggers, snakes and other things that she knows intellectually to be dangerous.

Fear stinks

4 The legendary smell of fear is for real. A 2008 Stony Brook University study found that scared people give off pheromones in their sweat that can trigger fear in others.

Scared sick

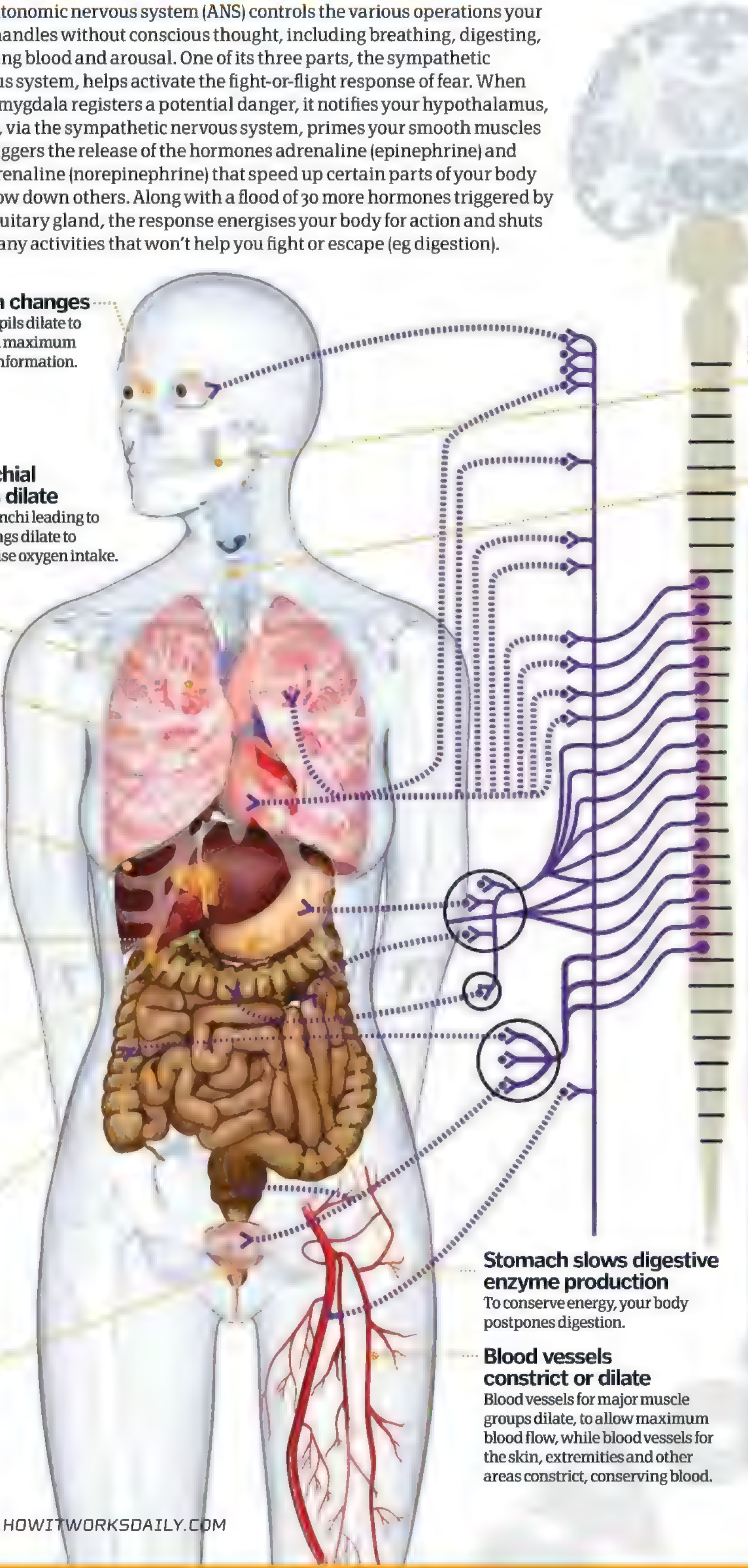
5 One of the non-essential systems fear puts on hold is the immune system. As a result, regular fear and anxiety can increase your susceptibility to disease.

DID YOU KNOW? *At least one person in ten experiences a panic attack now and then, typically triggered by a stressful event*

Automatic responses

The autonomic nervous system (ANS) controls the various operations your body handles without conscious thought, including breathing, digesting, pumping blood and arousal. One of its three parts, the sympathetic nervous system, helps activate the fight-or-flight response of fear. When your amygdala registers a potential danger, it notifies your hypothalamus, which, via the sympathetic nervous system, primes your smooth muscles and triggers the release of the hormones adrenaline (epinephrine) and noradrenaline (norepinephrine) that speed up certain parts of your body and slow down others. Along with a flood of 30 more hormones triggered by the pituitary gland, the response energises your body for action and shuts down any activities that won't help you fight or escape (eg digestion).

> *"While removing your fear system might make public speaking more fun, it would also make you easy prey"*



© DK Images

Vision changes

Your pupils dilate to bring in maximum visual information.

Bronchial tubes dilate

The bronchi leading to your lungs dilate to maximise oxygen intake.

Mouth dries up

The autonomic nervous system shuts down saliva production, an aid to food digestion that's deemed unnecessary in an emergency situation.

Trachea stays open

A body in action needs lots of oxygen, so the air passageway must remain wide open.

Stomach slows digestive enzyme production

To conserve energy, your body postpones digestion.

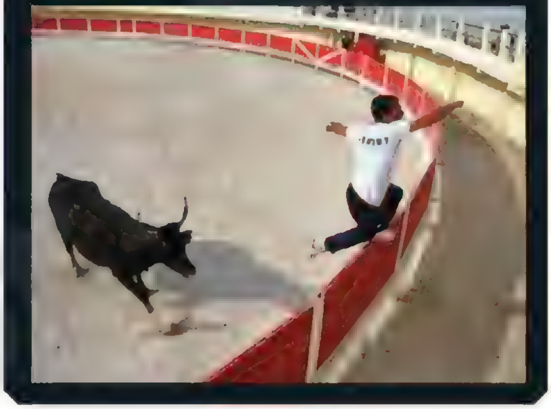
Blood vessels constrict or dilate

Blood vessels for major muscle groups dilate, to allow maximum blood flow, while blood vessels for the skin, extremities and other areas constrict, conserving blood.

Fight, flight and beyond

The fight-or-flight response, which was first identified by Harvard psychiatrist Walter Cannon in 1915, is a set of physical reactions you experience when you're afraid. While the things that trigger the response vary based on your personal experience, the response itself is hard-wired into your body, activated when your autonomic nervous system and your pituitary gland ready your body to face danger.

In recent years, some scientists have proposed updating the term to 'freeze, flight, fight or fright' to fit the current understanding of how the response plays out. When you detect a predator, which is likely to hone in on motion, the instinctual first response is actually to freeze, with the hope it passes you by. The second-best option is fleeing the scene. Only when you're attacked is fighting a good bet. Finally, playing dead through immobility – dubbed 'fright' – may lead the predator to loosen its grip enough to make an escape attempt.



"We evolved with the healthy fears of our primitive ancestors hard-coded into our brains"

hypothalamus floods your body with hormones that energise you for action and shut down any systems that are deemed non-essential. While the amygdala has been rallying the troops, other parts of your higher brain have been considering the available information and relevant past experiences to determine what's really going on and, ultimately, decide which course of action to take.

But how does your subconscious brain know what to fear in the first place? When you experience pain, the amygdala begins to associate sights and sounds you experienced with danger. If you repeatedly couple pain and a specific sight or sound, you can programme somebody to be afraid of just about anything. In the Twenties, psychologist John Watson conditioned the 11-month-old Little Albert to fear rats by smashing a cymbal behind his head every time he saw one. Watson did such a good job that Albert ended up fearing a variety of fluffy animals, and Santa Claus's beard to boot! Interestingly, this trick also works when we see somebody else experiencing pain connected to a stimulus.

Research suggests that it takes much less exposure to develop a fear of certain things, like snakes and heights, than others, like rainbows and lollipops. According to this theory, we evolved with the healthy fears of our primitive ancestors hard-coded into our brains, primed for activation from an early age. So, essentially, we come with a pre-programmed danger response system, a starter set of universal things to fear, along with the capacity to be scared of just about anything else. The rest is up to us.


Stimulus
You ignore a lot of the sights, sounds and smells your senses pick up, but something unexpected, such as a slithering snake, gets bumped to the top of the brain's hierarchy.

Eyes
Your eyes take in an immense amount of raw information, but none of it registers until your brain interprets it.

Phobias: when fear gets out of control

What are these irrational fears and how are they commonly treated?

According to researchers at Boston University's Center for Anxiety, 11 per cent of us have a phobia – an extreme, irrational fear of some object or situation. Specific phobias may begin with a traumatic event, experienced directly or observed, but this isn't actually the norm. Some phobias result from a person having an unrelated panic attack, brought on by general stress, in the presence of the object or situation. Others develop simply from hearing about dangers or being close to someone else with a fear.

No matter the source, ongoing anxiety and avoidance only serve to reinforce the phobia. This anxiety may be more about the reaction to the fear than the actual danger itself. Phobias do frequently run in families, possibly due to a combination of genetic predisposition and a shared environment.

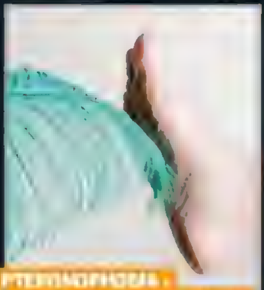
The leading phobia treatment is exposure therapy, which encompasses multiple techniques. In systematic desensitisation, patients learn deep relaxation techniques and then experience the objects or situations they fear while in a relaxed state. Flooding, in contrast, involves immersing the patient in exposure to the feared object or situation, with no preparation. The notion is that enough exposure shows the feared stimuli to be harmless. In modelling, the therapist confronts the fear, so that the patient will 'unlearn' the fear vicariously.

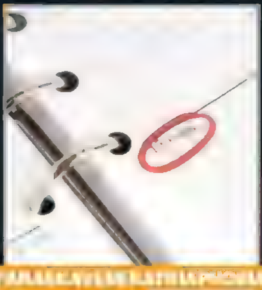
The face of fear

The components of a fearful face and body – eg the pulled back mouth, wide eyes, raised and scrunched eyebrows and tensed body – appear across different cultures, and never have to be taught. Many scientists believe this outward display of fear is an ingrained, universal expression that lets us instantly communicate to others that we've picked up on a nearby threat. In fact, fearful expressions may serve to cause instant fear in others. Through this form of emotional contagion, an entire group can get mobilised for fight or flight without each individual member having to pick up on the source of danger independently.

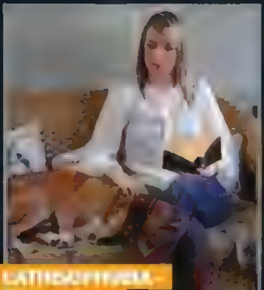
10 bizarre phobias

Because arachnophobia is just so passé...


PTERONOPHOBIA - Being tickled with feathers


PARASKEVIDEKATRIAPHOBIA - Friday the 13th


ARACHIBUTYROPHOBIA - Peanut butter sticking to the roof of your mouth


CATHISOPHOBIA - Sitting down


AUTOMATONOPHOBIA - Humanoid figures/dummies


© Andreplazza

Sea cucumber
Some of these species can eject most of their digestive system and other organs, confusing predators while they escape. Everything eventually regenerates.


© Gustavocarra

Hairy frog
A hairy frog species in Cameroon will break its own bones to extend a sharp claw-like bone straight through its toe pad – apparently in self-defence.


© L Shyamal

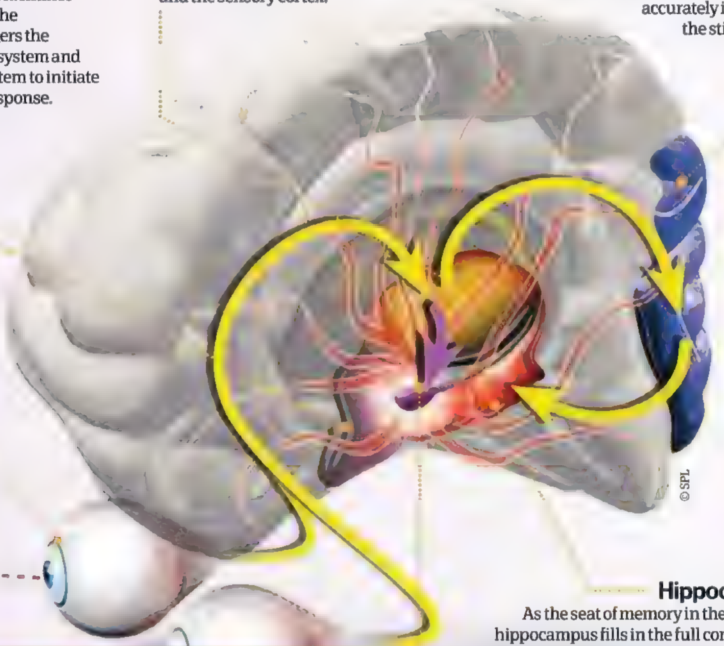
Malaysian carpenter ant
Under duress, the soldier class of a Malaysian ant species will contract abdominal muscles to explode itself, covering its attackers with a sticky toxin.

DID YOU KNOW? *Numerous studies have shown that fear is a powerful aphrodisiac for some people*

The fear response: deciding to be afraid

Our brains seem to assess danger instantly, but fear actually involves a multi-step, sophisticated process. The analysis happens along two paths. In the quicker 'low road', your amygdala registers a potential danger and begins the fight-or-flight response. In the slower but more considered 'high road', your cortex pieces together the bigger picture.

A false alarm highlights the difference between the two paths. When you see a snake by your feet and your heart skips, that's your amygdala sounding the alarm. When you realise it's just a garden hose and relax, your hippocampus cancels the alert. The logic is sound: better to lose your dignity because of a false positive than lose your leg because of a false negative.


© SPL

Thalamus
The thalamus is like a dispatcher, directing sensory information to the appropriate parts of the brain. It immediately passes potential danger signs on to the amygdalae and the sensory cortex.

Visual cortex
The occipital lobe works to make sense of what we see. In the fear response, it considers all visual information to accurately identify the stimulus.

Hypothalamus
When the amygdala identifies a potential danger, the hypothalamus triggers the autonomic nervous system and adrenal-cortical system to initiate the fight-or-flight response.

Amygdala
The amygdala associates sights and sounds with dangers that it has experienced in the past. When something matches a known danger, it notifies the hypothalamus.

Hippocampus
As the seat of memory in the brain, the hippocampus fills in the full context of the threat based on details of past experience. If it confirms the danger, the hippocampus tells the amygdala to keep the fight-or-flight response going. If it determines there is no risk, it tells the amygdala to shut it down.

Reacting to fear

Why do we sweat?
Sweat is your built-in air conditioner: the evaporating water on your skin cools you down. When afraid, your body triggers the cooling system in anticipation of physical exertion.

Why do our knees knock?
Knocking knees is a side-effect of increased blood flow to your muscles. If you don't start fleeing, the greatly increased muscle tension in your legs can make them shake uncontrollably.

Why do we shiver?
Blood vessels for the skin constrict to conserve maximum blood flow for the major muscle groups. Reduced blood flow to the skin has a chilling effect, which can trigger the shivering reaction, shaking muscles to generate heat.

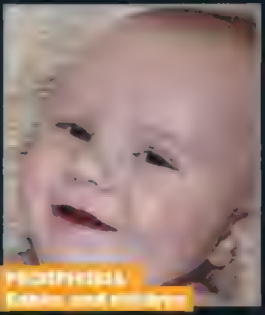
Why do we get goose bumps?
Adrenaline causes the muscles in our skin to contract, raising the hairs on our arms to create goose bumps. This doesn't do modern humans much good, but it would have made our furrier ancestors puff up, both to conserve heat and to make them appear bigger to attackers.

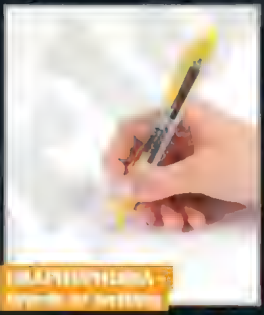
Why do our heart rates increase?
When you're ready to push your muscles to the limit to fight off a foe or flee, you need to provide them with as much blood as you can. You ratchet up your blood pump – ie your heart – to maximise the blood supply throughout the body.

Why do our pupils dilate?
During the fight-or-flight response, your pupils dilate, shifting your vision to a heightened, wider view of your surroundings, gathering as much information as it can about the situation.

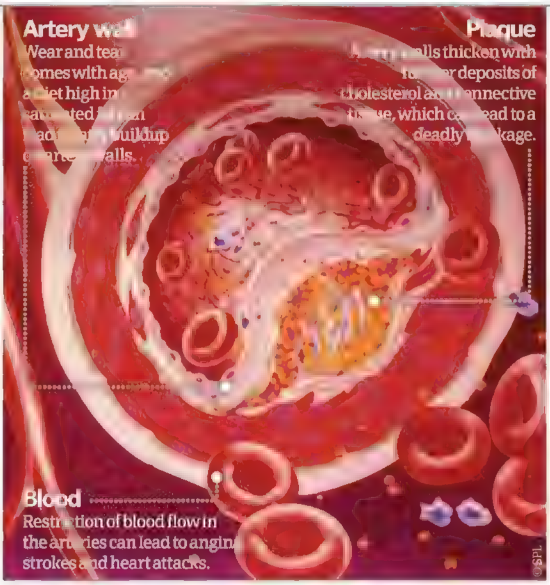
Why do we breathe faster and deeper when scared?
Increased blood flow isn't much good unless the blood is sufficiently oxygenated. Respiration steps up a gear to bring in the oxygen you need.

Why do we scream?
The prevailing theory is that screaming doubles as a call for help from others and as a way to intimidate or scare off the threat.





> "Cholesterol itself isn't unhealthy – in fact, you wouldn't be able to live without it"



Is cholesterol bad for you?

Is this substance as evil as we hear?

Cholesterol is a fatty molecule in the blood and, generally speaking, having too much is bad: it can stick to the walls of your arteries and increase the risk of heart disease. Most foods, with the exception of offal, eggs and shellfish, don't contain any cholesterol, but many contain saturated fats, which are turned into cholesterol by the liver. However, cholesterol itself isn't unhealthy – in fact, you wouldn't be able to live without it. The body uses cholesterol as a kind of padding, coating the outer membranes of all our cells and insulating nerve fibres, helping signals travel properly to and from the brain. It's also a fundamental part of the endocrine system, as all steroid hormones (eg oestrogen) are synthesised from cholesterol. A good diet and regular exercise can keep cholesterol within a healthy range for most people.

How are unwanted tattoos removed?

Thanks to advances in technology, tattoos can now be erased using some specialised tools

Today tattoos are usually removed with high-powered lasers. Lasers are used as they allow the tattoo's ink pigment to be fragmented to the extent that it can be shed by a human's natural skin growth and healing processes. The reason the ink has to be acted upon with a high-powered laser is due to its relatively deep level in the skin's dermis; conventional medical lasers aren't of sufficient strength. Additionally, the droplets of pigment are far too large to be broken down chemically.

The most common type of high-powered tattoo laser system used today is the Q-switched variety. These lasers differ to standard ones in two key ways. First, they produce pulses of laser light rather than a continuous beam and, second, these pulses have an extremely high peak power (in the gigawatt range). When used on a person's skin, the tattoo's ink pigments can be 'flashed' with a very controlled strength laser pulse over a short period of time, fragmenting the ink instantly and causing minimal temporary scarring to the skin.

Laser power

Tattoo removal lasers differ to other types, as shown by this trio

Tunable dye laser
Tunable dye lasers are generally too weak to penetrate the skin at all. They are commonly found in laser pens.

Argon laser
Argon lasers penetrate the epidermis (upper layer of skin) and can be used to treat haemangioma-type conditions (a form of benign tumour) that can form here.

Carbon dioxide laser
The carbon dioxide laser penetrates the epidermis down to the dermis, allowing the fracturing and removal of tattoo pigments deep in the skin.

© SPL

Vulcanisation explained

Vulcanised rubber is an incredibly versatile and useful material, but how is it manufactured?

Vulcanisation is a chemical process that converts natural rubber into a tougher, more durable form. It achieves this through the addition of numerous curatives – substances that can enhance a material from its organic state – including sulphur, peroxides and acetoxysilane.

These curatives work by modifying rubber's structural form, adding numerous strengthening crosslinks between its individual polymer chains. This transforms rubber and similar materials from sticky, easily deformable substances into materials that, while still pliable, are far more resistant to wear.

Focusing on the most common curative, sulphur, the vulcanisation process works as follows in the creation of a typical car tyre. First natural rubber compounds are harvested and combined with sulphur and a variety of additives. These additives include accelerators, such as vulcafor, as well as antidegradants, such as paraffin waxes. The accelerators act both to speed up the crosslink creation process and also improve the quality and number of crosslinks between the rubber's polymer strains. Antidegradants, meanwhile, prevent the rubber breaking down during the intense vulcanisation process.

Next, the mixture is dumped into a compression mould, which in this case is tyre-shaped. The mould is then 'cooked' in a pressurised oven for about ten minutes at 170 degrees Celsius (338 degrees Fahrenheit). The heat and pressure, in combination with the mixture's composition, catalyse the crosslink process and sustain it at a rapid level. Once cooled, the mould is removed, releasing the base tyre for further processing.

© Goodyear

> "Autografts are skin grafts taken from the patient's own body, eg the buttocks"

How skin grafts work

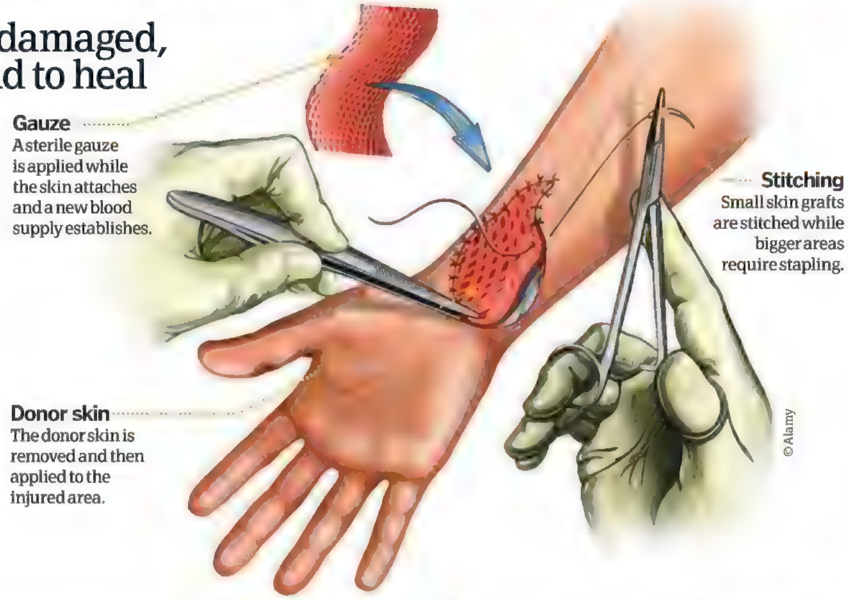
When our body's largest organ is damaged, sometimes it needs a helping hand to heal

Skin grafting is a medical procedure where a portion of skin is removed and stitched onto another part of the body. There are many cosmetic and medical reasons why this might be necessary: serious burns, surgery, tattoo removal and some medical conditions (skin cancer or diabetes, for example) might all necessitate skin grafting.

Autografts are skin grafts taken from the patient's own body, usually the buttocks, neck or back of the arm. Depending on the size of the area that it's removed from, it's then stitched or stapled closed again and the new skin applied to the injured area. Allografts and xenografts, meanwhile – taken from other humans and animals, respectively – are temporary grafts.

But perhaps most interesting is the artificial 'skin' called Integra, made of animal collagen that gives the damaged part an organic scaffolding for new skin to grow into. This is usually used in cases of extreme burns where there isn't enough healthy skin for an autograft.

Skin graft surgery



Gauze A sterile gauze is applied while the skin attaches and a new blood supply establishes.

Stitching Small skin grafts are stitched while bigger areas require stapling.

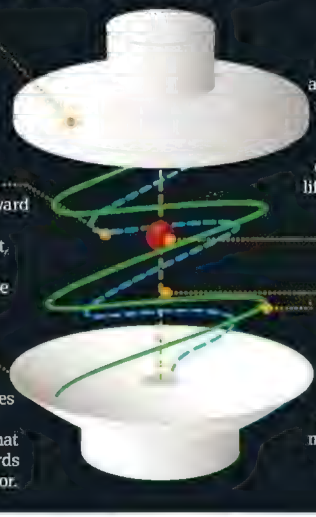
Donor skin The donor skin is removed and then applied to the injured area.

© Alamy

Acoustic levitation

How can we lift objects with sound alone?

Acoustic levitation is a method of suspending an object – solid or fluid – in a medium such as air using acoustic radiation pressure. The pressure comes from intense sound waves, which are generated by a transducer (any device that converts one form of energy into another). The waves are then bounced back to cause interference and generate standing, or stationary, waves by a reflector. These waves vibrate back and forth in small segments rather than travelling continuously in one direction; this is key as it's through their stasis that foreign objects can be suspended, hanging between the transducer and reflector. The object levitates as the countering areas of pressure in the standing waves create a kind of pressure equilibrium within the medium, negating the weak force of gravity.



Reflector This bounces the longitudinal pressure waves directly back towards their original source.

Object While there is no theoretical limit to an object's weight or size, currently only small objects less than a couple of kilograms can be lifted. Water droplets are very common.

Standing wave As the original upward sound waves and reflected ones meet, compressions and refractions generate stationary waves.

Nodes The standing waves have polarised nodes, areas of minimum pressure, and antinodes, areas of maximum pressure, that cancel each other out.

Transducer This generates intense sound waves – ie longitudinal pressure waves – that are directed upwards towards the reflector.

THE STATS
TURNING POINTS

BOILING POINT OF WATER: 100°C (212°F)
FREEZING POINT OF WATER: 0°C (32°F)
BOILING POINT OF OXYGEN: -183°C (-297°F)
MELTING POINT OF OXYGEN: -218°C (-361°F)
BOILING POINT OF HYDROGEN: -253°C (-423°F)
MELTING POINT OF HYDROGEN: -259°C (-435°F)

DID YOU KNOW? *There are lots of other states of matter aside from the classical three, with more being proposed all the time*

States of matter explained

Every object on Earth fits into one or more of these phases, but how do they differ at an atomic level?

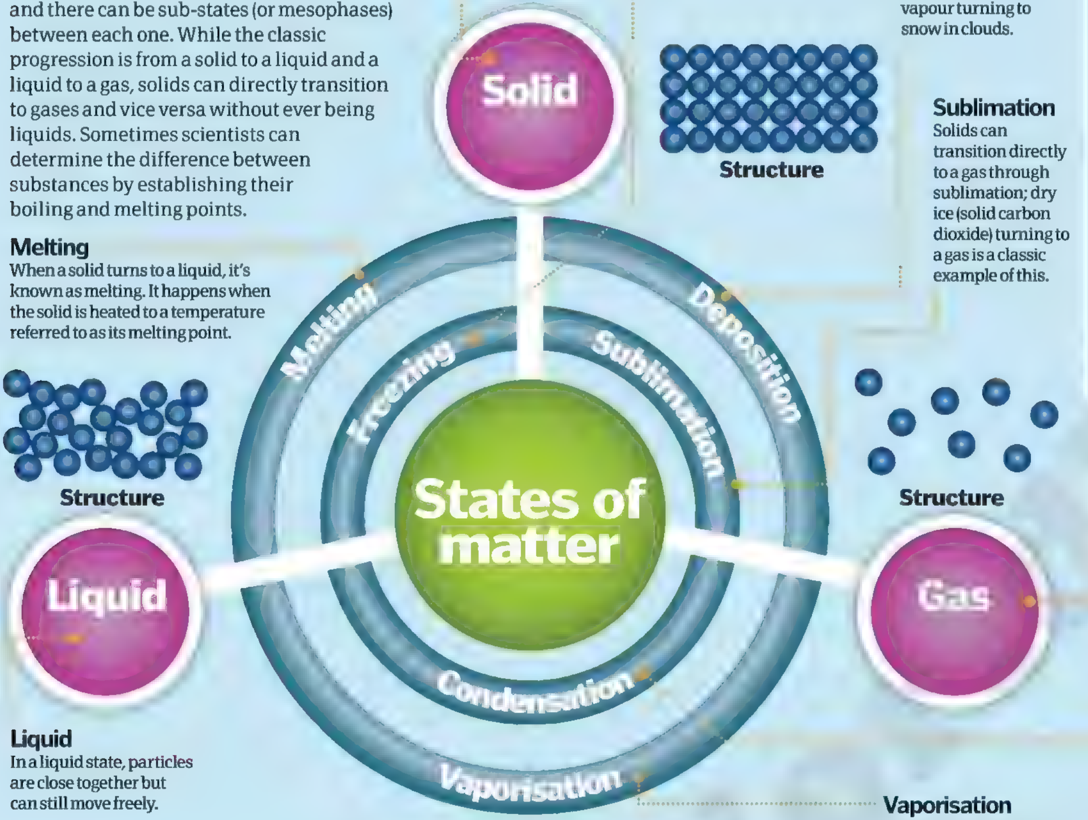
Every single object is either a solid, a liquid, a gas or some combination of the three. Some things can move between states, and some can't. Your bookcase is going to remain a solid, for example, but water changes depending on the temperature. But a block of water ice still has the same chemical makeup as water in its gaseous form (steam). So what's the difference? A solid object stays the same shape and takes up the same amount of space, or volume. Liquids take up the same amount of space but adapt to the shape of a container, while gases expand. But to really see the difference, you'd need to check things out at a microscopic level.

If you looked at water in its various phases under a powerful microscope, you would see that the particles in each behave very differently. When it's a vapour (ie steam), the water particles vibrate and are moving very quickly. They're loose and slide freely around with no particular arrangement. In comparison, liquid water particles also vibrate and can move around easily, however they're more tightly packed and don't move anywhere near as fast as their gaseous counterparts. Finally, a block of solid ice doesn't move (that is, the particles still vibrate but not enough to go anywhere). This is because its particles are tightly and rigidly packed together in an ordered pattern.


Glacial ice covers roughly ten per cent of land on Earth and forms seven per cent of the oceans

Phase transitions

No matter what the substance, the names of the state changes, or phase transitions, remain the same. When and how it changes depend on the temperature and pressure, and there can be sub-states (or mesophases) between each one. While the classic progression is from a solid to a liquid and a liquid to a gas, solids can directly transition to gases and vice versa without ever being liquids. Sometimes scientists can determine the difference between substances by establishing their boiling and melting points.



Solid
Particles in solids are densely packed and barely move at all.

Freezing
Liquids transition to solids when they reach a specific temperature for the substance known as its freezing point.

Deposition
Also called desublimation, this is when a gas moves directly to a solid without passing through the liquid phase, such as water vapour turning to snow in clouds.

Sublimation
Solids can transition directly to a gas through sublimation; dry ice (solid carbon dioxide) turning to a gas is a classic example of this.

Melting
When a solid turns to a liquid, it's known as melting. It happens when the solid is heated to a temperature referred to as its melting point.

Liquid
In a liquid state, particles are close together but can still move freely.

Gas
Gases have particles that move quickly and are spaced widely apart.

Condensation
Condensation is the mesophase between a gas and a liquid.

Vaporisation
Liquids transform into gases through vaporisation.

Plasma: the fourth state

The three states of matter – liquid, gas and solid – are considered the 'classical states', because there are other states of matter too. In fact, throughout most of the universe matter exists as plasma, a state that can occur when certain gases are heated, causing some of the particles in the gas to become ionised. Ionisation means that the number of electrons in an atom is no longer equal to the number of protons – then the particles are either positively or negatively charged. So plasma as a whole is neutral, as it's made up of roughly equal numbers of positive and negative ions.

All stars are made predominantly of plasma, and the spaces between the stars and galaxies are full of it. It's also present on Earth in phenomena like lightning and the polar auroras. It can be artificially created too and is used in things like TVs, lasers and neon signs.

> "Scientists have begun to ascertain which parts of the brain function as we form different thoughts"

IS IT POSSIBLE TO SEE OUR THOUGHTS?

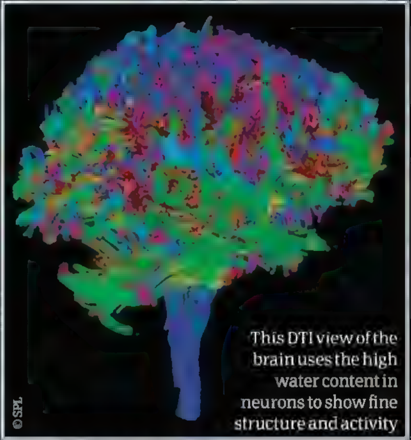
The brain is perhaps the most vital of the body's vital organs, yet in many ways it's also the least understood


This CT scan of the brain has fused PET images over it, showing activity of different regions when the patient is exposed to a range of stimuli

© SPL

At its most simple level, the brain is a series of interconnecting neurons that relay electrical signals between one another. They are 'all or none' transmitters as, like a computer, they either transmit a signal (like a binary '1') or do not ('0'). Different neurons are receptive to different stimuli, such as light, touch and pain. The complex activity of these neurons is then interpreted by various parts of the brain into useful information. For example, light images from the eye are relayed via the optic nerve to the occipital cortex located in the back of the skull, for interpretation of the scene in front of you.

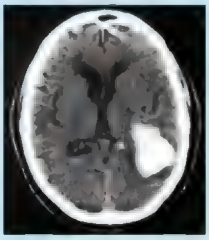
The generation and interpretation of thoughts is a more complex and less well understood process. In fact, it is a science of its own, where there are many definitions of what a 'thought' is, and of what defines consciousness. In an effort to better define these, doctors, scientists and psychologists have turned to novel imaging techniques to better understand the function of our minds. Research into understanding brain activity and function has led to some of the most advanced imaging techniques available. This has helped to treat conditions such as Alzheimer's dementia, epilepsy and stroke, as well as mental illnesses where there is not necessarily a physical problem within the brain. It has also led to benefits for imaging other diseases in other parts of the body, including several forms of cancer.


This DTI view of the brain uses the high water content in neurons to show fine structure and activity

© SPL

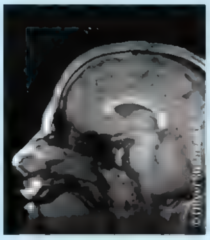
These advanced imaging techniques include scans to produce images of the anatomical structure of the brain, and interpretation of energy patterns to determine activity or abnormalities. Scientists have started to ascertain which parts of the brain function as we form different thoughts and experience different emotions. This means we are very much on the brink of seeing our own thoughts.

How can we view the brain?



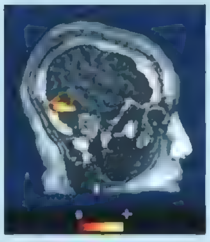
Computed tomography (CT)

This combines multiple X-rays to see the bones of the skull and soft tissue of the brain. It's the most common scan used after trauma, to detect injuries to blood vessels and swelling. However, it can only give a snapshot of the structure so can't capture our thoughts.



Magnetic resonance imaging (MRI)

MRI uses strong magnetic fields to align the protons in water molecules in various body parts. When used in the brain, it allows intricate anatomical detail to be visualised. It has formed the basis of novel techniques to visualise thought processes.



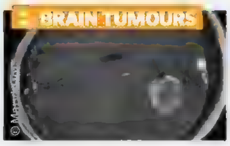
Functional MRI (fMRI)

This form of MRI uses blood-oxygen-level-dependent (BOLD) contrast, followed by a strong magnetic field, to detect tiny changes in oxygen-rich and oxygen-poor blood. By showing pictures to invoke certain emotions, fMRI can reveal which areas are active during particular thoughts.

© Thierry Geoffroy

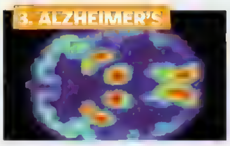
CT scan

Fast and easily accessible 24 hours a day, these scans can identify life-threatening bleeding within the skull for neurosurgeons to stop.



3D MRI

These 3D scans show intricate anatomical details of brain tumours, particularly in relation to the surrounding structures. This enables doctors to determine if they can be safely removed or not.

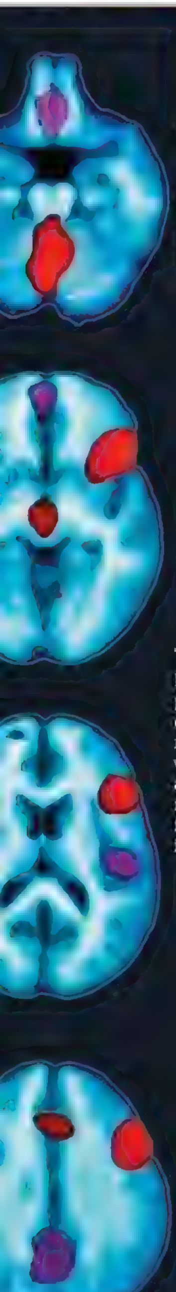


PET scan

This functional imaging is allowing researchers to test novel drugs and treatments to prevent progression of this serious brain disorder.

DID YOU KNOW? *CT scanning of the brain was invented in the early-Seventies*

Picking apart the brain



The frontal lobes
The frontal lobes of the folded cerebral cortex take care of thought, reasoning, decisions and memories. This area is believed to be largely responsible for our individual personalities.

The sensory and motor cortexes
The pre- and post-central gyri receive the sensory information from the body and then dispatch orders to the muscles, in the form of signals through motor neurons.

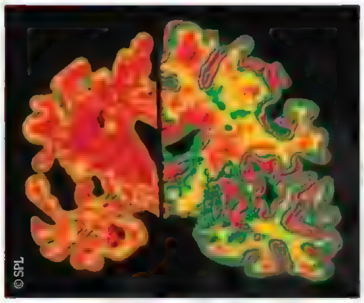
The occipital cortex
In the posterior fossa of the skull, this cortex receives impulses from the optic nerves to form images. These images are in fact seen upside down, but this area enables them to be interpreted the right way up.

The brainstem
Formed from the midbrain, pons and medulla oblongata, the brainstem maintains the vital functions without us having to think about them. These include respiration and heart function; any damage to it leads to rapid death.

The cerebellum
The cerebellum is responsible for fine movements and co-ordination. Without it, we couldn't write, type, play musical instruments or perform any task that requires precise actions.

© Alamy

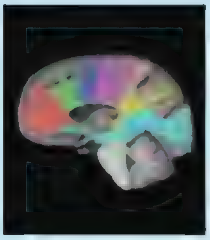
The pituitary gland
This tiny gland is responsible for hormone production throughout the body, which can thus indirectly affect our emotions and behaviours.



© SPL

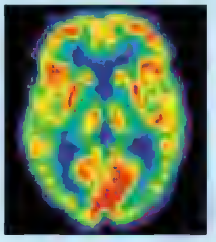
Imaging Alzheimer's

Alzheimer's disease is a potentially debilitating condition, which can lead to severe dementia. The ability to diagnose it accurately and early on has driven the need for modern imaging techniques. The above image shows a PET scan. The right-hand side of the image (as you look at it) shows a normal brain, with a good volume and activity range. On the left-hand side is a patient affected by Alzheimer's. The brain is shrunken with fewer folds, and a lower range of activity – biologically speaking, there are far fewer neurons firing.



Diffusion tensor imaging (DTI)

This MRI variant relies on the direction of water diffusion within tissue. When a magnetic gradient is applied, the water aligns and, when the field is removed, the water diffuses according to a tissue's internal structure. This allows a 3D image of activity to be built up.

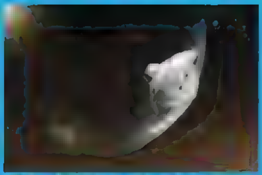


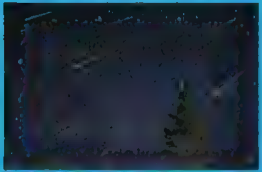
Positron emission tomography (PET)

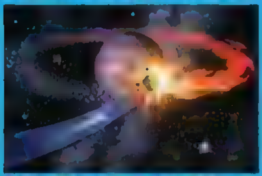
This bleeding-edge technology detects gamma rays emitted from biologically active tissues based on glucose. It can pick up unusual biological activity, such as that from cancer. There have been recent advances to combine PET with CT or MRI to obtain lots of data quickly.

Welcome to... SPACE

Could the Red Planet ever have harboured life? Does it still? Those questions have mystified [illegible] for centuries, and come August, we might finally have our answers – if the MSL mission goes to plan. Also in Space this month read about the most popular theory as to how Earth's only natural satellite – the Moon – came into existence, as well as the way we can forecast when meteors will fall from the sky







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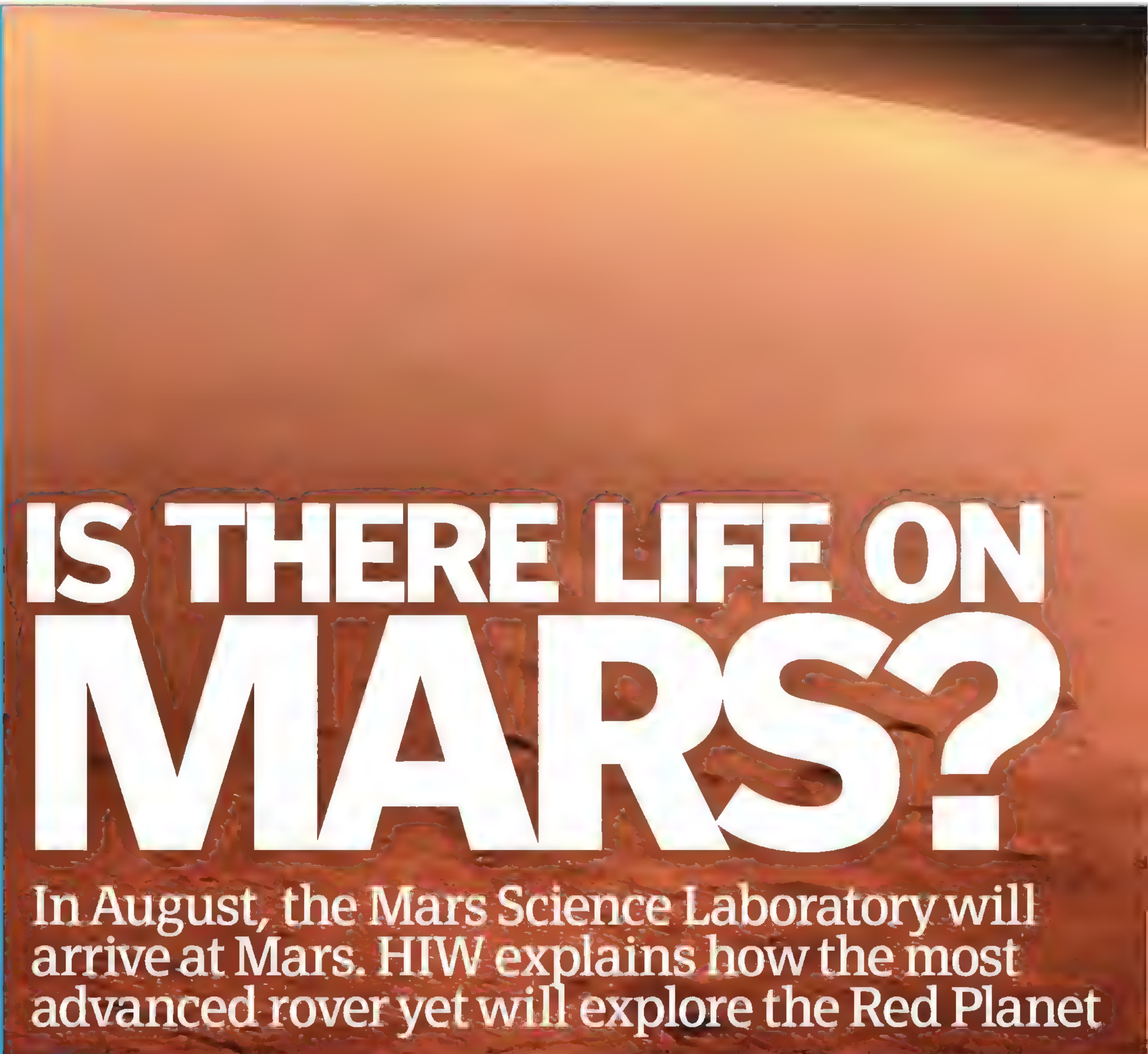


IS THERE LIFE ON MARS?

In August, the Mars Science Laboratory will arrive at Mars. HIW explains how the most advanced rover yet will explore the Red Planet

It seemed a lonely existence just to see as far as what we thought was the edge of the universe 100 years ago. Turns out, it was just the far fringes of the Milky Way. Now our most powerful orbital telescopes can send us images of galaxies billions of light years from Earth, and though this has inspired hope in astronomers of eventually detecting intelligent life somewhere in the billions of worlds out there, until then our limited technology has left us scraping the surface of a desolate red-coloured planet that on average is around 225 million kilometres (140 million miles) from Earth – a mere eight light minutes. That's a cosmic heartbeat away that will take the Mars rover Curiosity nine months to reach, and though the odds of mankind discovering life on another planet within our own lifetimes are similarly astronomical, Curiosity is keeping the dream alive. Once it has landed, its job will then be to study Mars for a full Martian year (about 687 Earth days), gathering samples and exploring its surface like no other rover before it, making the most comprehensive assessment yet of whether Mars was ever capable of supporting life.

This is far from the first time NASA, or any other governmental space organisation, has undertaken a mission to investigate our second-closest planetary neighbour in the Solar System. In the last 50 years, four different space agencies have sent 39 various probes, satellites and rovers to the Red Planet.

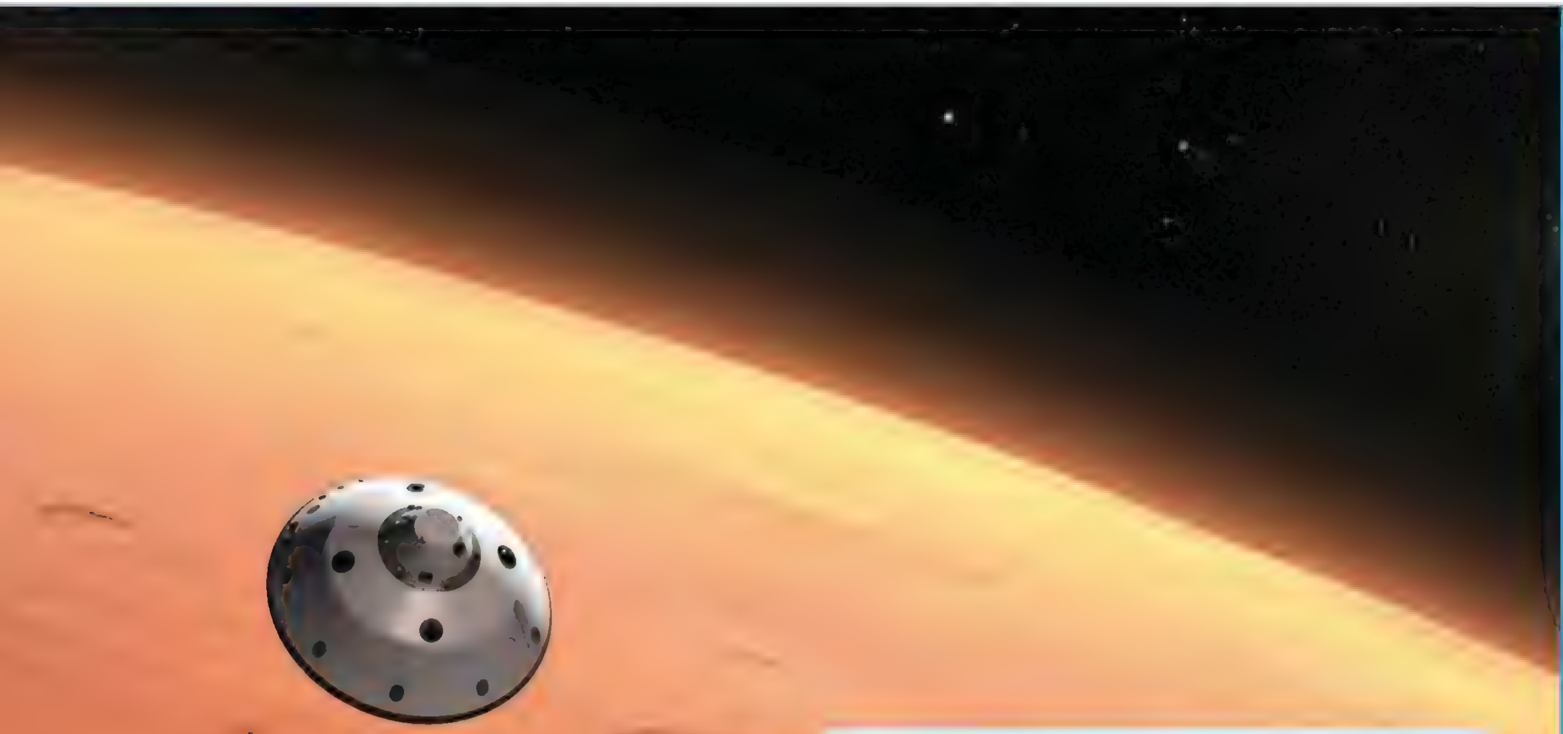
The first two, Korabl 4 and 5, were Martian probes launched on 10 and 14 October 1960, respectively, by the USSR and both of which were abject failures, unable even to obtain orbit around the Earth. The USSR's next attempt in 1962, Korabl 11, did achieve Earth orbit but then broke apart. Korabl 13 suffered the same fate as Korabl 11 and the US's first shot at a Mars flyby with NASA's Mariner 3 failed to release a heatshield when it entered Earth orbit, the weight of which made it too heavy to achieve a Mars trajectory. Like so much other space junk, the terminated Mariner 3 project is now fated to orbit the Sun forever.

So it took a total of six attempts at getting to Mars before Mariner 4 flew past the planet in 1964 and took 21 photos of the surface in unprecedented detail. Since then 16 missions to Mars have overcome the difficult launch stage and achieved their goal, sending back data that has increased exponentially with our own space exploration technology. Based on the vital information gathered by the first successful soft landing on

THE STATS
MSL IN NUMBERS

ATMOSPHERIC ENTRY SPEED: **21,240km/h**
COST: **$2.5bn (£1.6bn)**
GALE CRATER DIAMETER: 154km
LASER RANGE: 7m
MOBILITY RANGE: **20km**
ON-BOARD CAMERAS: 17

DID YOU KNOW? *Thanks to Spirit and Opportunity, we already know that Mars used to be much warmer and wetter*



Mars, Viking 1, NASA's 1975 Viking 2 craft was able to land in a more advantageous position closer to the Martian north pole, to help take the photos that produced the Martian atlas that's still used today.

In 1996 the Mars Global Surveyor (MGS) became one of the most successful Mars orbiters ever, taking more images than all other Mars missions put together. And it seems that NASA in particular has been getting much better at the Mars gig recently; since the turn of the millennium, the US space agency has launched five missions to the Red Planet, all of them a resounding success with two that have exceeded their operating lifetime by 15 times the original NASA warranty. The Mars Exploration Rover Spirit was launched in June 2003 and landed in January 2004, moving several kilometres across the surface before it found evidence of water existing some time in the past. Spirit's success was amplified by the fact that it has hobbled with one stuck wheel for years, a blessing in disguise for NASA as the public warmed to the intrepid vehicle while it dutifully soldiered on despite the odds.

Opportunity was launched a month after Spirit and is still active today, having roved a 33-kilometre (20.5-mile) stretch to a crater called Endeavour that's 22 kilometres (13.7 miles) in diameter; it is currently exploring this feature. The tenacity of both Spirit and Opportunity bodes well for NASA's next generation of Mars rover, the Curiosity, which launched on 26 November 2011 and is due to make its landing on 6 August 2012.

Why go to Mars?

The primary reason we're incessantly firing more and more investigatory craft at Mars than any other planet is, as simple as it sounds, that it's close to us. Not as close as Venus, but the surface of the second-nearest planet to the Sun has an atmospheric pressure 92 times that of Earth and a 462-degree-Celsius (863-degree-Fahrenheit) temperature that's hot enough to melt zinc. That was enough to put the Soviet probe Venera 7 out of action within an hour when it landed on Venus in 1970, and enough to put NASA off sending its own lander to be cooked and crushed on the deadly planet until nearly a decade after. By contrast, the thin atmosphere and -140 to 20-degree-Celsius (-220 to 68-degree-Fahrenheit) temperature range on the surface of Mars is far less hostile to our intrepid robots.

Unlike Venus, Mars also exists in the same 'Goldilocks' orbital zone as the Earth – that balmy circumstellar habitable region where a planet with the right atmospheric pressure can maintain liquid water on its surface. Moreover, we've already discovered evidence for the wet stuff on Mars – and where there's liquid water, there's the potential for life.

All Images © NASA

> "On 5 August 2012, the MSL will enter the Martian atmosphere, 125km (78mi) above the planet"

Journey to the Red Planet

Three months after the successful landing of both Spirit and Opportunity, NASA began research for instruments to be used aboard the Mars Science Laboratory. But exploring and experimenting on Mars was only half the mission; first Curiosity needed to get to Mars. At the size and weight of a small car – five times that of Curiosity's predecessors – NASA couldn't simply rely on the old technology to safely deliver the rover.

There were several factors to consider: how to escape Earth's gravity and set Curiosity on the right trajectory, keeping a steady course, entering Mars's atmosphere and then safely landing.

First of all, the launch vehicle had to provide the appropriate amount of velocity needed to escape Earth's gravity. Considering the fully loaded Curiosity weighs in at 900 kilograms (2,000 pounds), NASA chose the tried-and-tested Atlas V 541, a variation on the Atlas V ELV (expendable launch vehicle) family with a near-perfect record since its maiden voyage in 2002. When fuelled with the liquid oxygen and kerosene propellant that makes up half its weight, the Atlas V can provide a whopping 387,500 kilograms-force (854,300 pounds-force) of thrust.

Attached to the Atlas V were four solid rocket motors. These were designed to give the Atlas V the additional boost it required to achieve orbit. Their solid fuel and oxidiser propellant provided this necessary push and, once ignited, burned until their fuel was completely expended before falling back to Earth. Once the Atlas had achieved the right altitude, the brawn of the mission had done its job and it was time for the brains to take over.

The second stage of the launch involved the Centaur, the upper-stage rocket that housed not only a liquid hydrogen and oxygen engine but the Curiosity payload and the flight control computer. The Centaur fired twice with up to 10,100 kilograms-force (22,300 pounds-force) of thrust using the computer to precisely adjust its direction: once to insert itself into low Earth orbit, then once again to launch Curiosity in its spacecraft on its way to Mars with a carefully calculated altitude and rate of spin. Having shed its protective fairing, the active part of the Mars Science Laboratory had gone from a pre-launch, complete shuttle weight of 531,000 kilograms (1.17 million pounds) to a cruise configuration of 3,893 kilograms (8,463 pounds).

The MSL cruise stage doesn't work all that differently from the cruise control in a terrestrial car. Speeding along at a velocity (relative to the Sun) of 30,150 kilometres (18,734 miles) per hour, it will make a total of six corrections to its trajectory along the way. The flight computer is currently doing this using an on-board star scanner that tracks the position of the cruise stage in relation to the stars, powering up its hydrazine-fed propulsion system when required. Computers will monitor the spacecraft over the nine-month transit, pumping coolant around systems that get hot, like the solar panels, while insulating instruments sensitive to the cold from the near-absolute-zero temperatures of space.

On 5 August 2012, the MSL will enter the Martian atmosphere, 125 kilometres (78 miles) above the planet. It's here that the aeroshell (a kind of heatshield) will separate itself from the now redundant cruise stage and begin its journey down to the surface. A parachute will deploy at 11 kilometres (6.8 miles) from the surface, and the aeroshell will fall away at eight kilometres (4.9 miles) as the MSL pings the surface of Mars with radar to adjust its position for an optimum landing. The entire backshell, parachute and all will separate from the MSL at an altitude of 1.6 kilometres (0.9 miles) where a new, rocket-guided landing system slows its descent. The final delivery system is a sky crane, which will lower Curiosity onto the surface for a soft landing.

1 Cruise stage In its approach to Mars, NASA engineers make their final calculations.

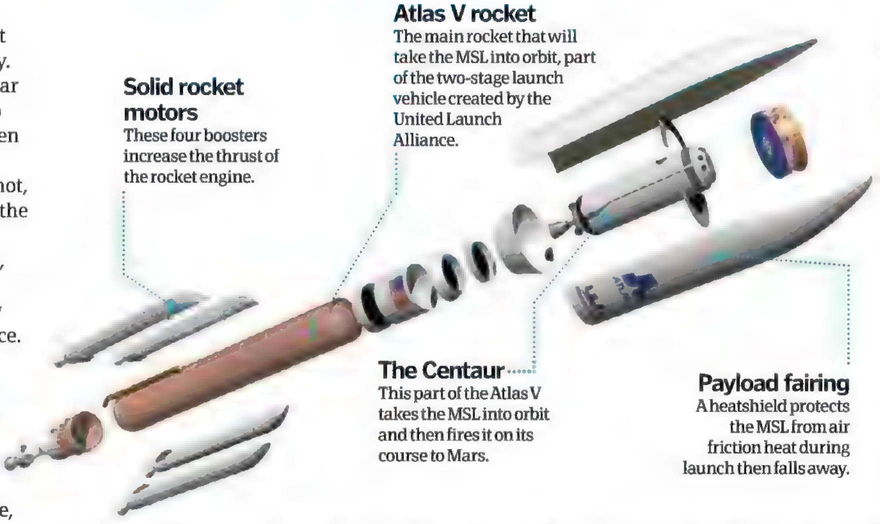
2 Cruise separation As it enters the Martian atmosphere, the cruise phase separates from the MSL.

3 Guided entry Small rockets on the MSL craft fire to control its descent.

Danger: Mars approaching!

[illegible]

The Atlas V 541



Atlas V rocket The main rocket that will take the MSL into orbit, part of the two-stage launch vehicle created by the United Launch Alliance.

Solid rocket motors These four boosters increase the thrust of the rocket engine.

The Centaur This part of the Atlas V takes the MSL into orbit and then fires it on its course to Mars.

Payload fairing A heatshield protects the MSL from air friction heat during launch then falls away.

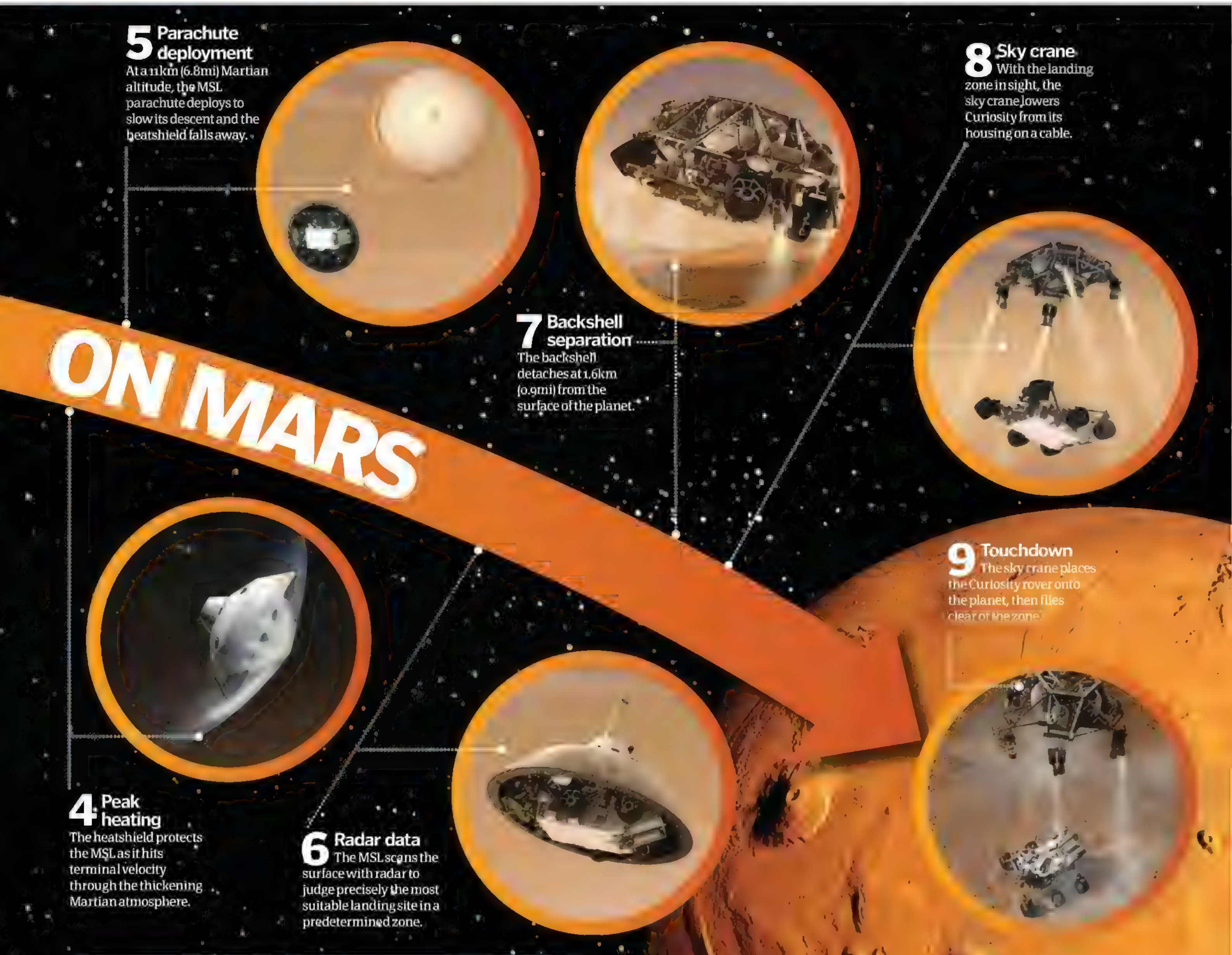
RECORD BREAKERS
MEGA RIFT

4,023KM

BIGGEST CANYON

Valles Marineris on Mars is the Solar System's biggest canyon, at 4,023km (2,500mi) long, and up to 8km (5mi) deep and 644km (400mi) wide. On Earth, it would stretch the full length of the US.

DID YOU KNOW? The MSL project cost $900m (£581m) more than its projected $1.6bn (£1.03bn) estimate in 2006



4 Peak heating
The heatshield protects the MSL as it hits terminal velocity through the thickening Martian atmosphere.

5 Parachute deployment
At a 11km (6.8mi) Martian altitude, the MSL parachute deploys to slow its descent and the heatshield falls away.

6 Radar data
The MSL scans the surface with radar to judge precisely the most suitable landing site in a predetermined zone.

7 Backshell separation
The backshell detaches at 1.6km (0.9mi) from the surface of the planet.

8 Sky crane
With the landing zone in sight, the sky crane lowers Curiosity from its housing on a cable.

9 Touchdown
The sky crane places the Curiosity rover onto the planet, then flies clear of the zone.

The landing site

Choosing the right landing site was critical. The last thing NASA wanted was to put Curiosity in a position where communication might be made difficult or in a region of less scientific interest. Although the rover is capable of articulate movement, at a speed of 144 metres (450 feet) an hour on smooth terrain, the area of Mars it can effectively explore during its mission is limited. Selection began in 2008 with NASA profiling an ideal landing site, which should have: 'clear evidence of a past or present habitable environment', a 'favourable geologic record' – meaning preserved layers of rock exposed at the surface, evidence of past water, good accessibility for the rover and all of this located near a safe landing zone. Sites were narrowed from over 30 candidates down to the final selection in 2011: Gale Crater, a 154-kilometre (96-mile)-diameter remnant of an ancient impact that has a mountain called Aeolis Mons that is five kilometres (three miles) high in its northern portion. In its 3.5 billion years it has formed sedimentary layers and has evidence of a wet history. Curiosity will land on a relatively smooth plain just north of Aeolis Mons.

> "The Curiosity has a much bigger range of movement than the Spirit or Opportunity rovers"

Martian experiments

Once Curiosity has been dropped off, then what? 40 years ago it was enough to get a man to the Moon and have him stick a flag in the ground. Today, despite the radical new methods involved in getting Curiosity to Mars, NASA's requirements of any extraterrestrial mission extend far beyond bragging rights.

The nature of many of NASA's future projects hinges on the success of the MSL's innovative technologies. The target landing site, for example, is an area of around 20 kilometres (12 miles) in length, a fivefold improvement in precision using the sky crane/rocket descent technique. Without this new tech, landing so close to the edge of the Gale Crater wall would be impossible. In a worst-case scenario, should the MSL lander fail to insert Curiosity safely or effectively into the landing zone, it may preclude similar Martian sites in the future. As the new system is capable of landing a vehicle even bigger than Curiosity (which is five times heavier than its predecessors, Spirit and Opportunity), a proven safe delivery onto Mars becomes even more important.

You'd have thought that, as Curiosity has been in development for nearly eight years, the NASA team would be keen to send the rover off to explore as soon as its wheels touch the ground. But as much as the scientists might like to do that, the engineers need to run a host of system checks that mean Curiosity won't be going anywhere until at least five days after landing. During this time, they will essentially be ensuring that the wheels aren't stuck and that the rover is capable of moving away from its landing position without embedding itself in soft sand, an irrevocable situation in which its predecessor Spirit found itself two years ago. But once that's done, the fun part of the MSL mission starts…

The nature of this mission is one of discovery, so NASA hasn't carved in stone exactly what the Curiosity will be doing in its 680 or so Earth days on Mars, though scientists do have a rough plan. Apart from maintenance and a 20-sol period (a Martian day, referred to as a sol, is nearly 40 minutes longer than an Earth day) when Mars is on the far side of the Sun, the Curiosity's activities will be prioritised according to what it can find. The Curiosity has a much bigger range of movement than Spirit or Opportunity, rated for roaming up to 20 kilometres (12.4 miles) from the landing site. As a result, a major portion of its time will be taken up driving to scientifically interesting sites and collecting samples.

There is a huge range of possible ways the MSL mission might unfold in the Martian year that it spends there. However, using what we already know about Mars and the landing zone, NASA has compiled a number of day-to-day activities into logical sequences that form five separate scenarios, measured in tactical windows known as sols. Traverse sols mostly involve roving between target sites, triggered by a ChemCam observation. Reconnaissance sols involve surveying a site prior to detailed study, triggered again by the ChemCam plus the Mars Hand Lens Imager (MAHLI). Approach sols are triggered by a previous sol and place a patch of soil or rock within the working area of the rover's robotic arm, while contact sols incorporate the arm-mounted instruments on the MSL to measure and observe a target.

Last but not least, sampling and analysis sols will most likely prove the most fascinating out of these five scenarios. The MSL will spend some time passing rock and soil samples through a sieve and into CheMin and Sample Analysis at Mars (SAM). In SAM, a suite of instruments will check for the presence of hydrogen, oxygen, nitrogen and other elements associated with life. Meanwhile, CheMin will check for minerals like gypsum and jarosite, which indicate the presence of water and might point to a previous Martian environment that supported life.

The Curiosity and its payload

A closer look at some of the key equipment

Power
A radioisotope thermoelectric generator (RTG) uses the predictable rate of plutonium's radioactive decay to generate electricity from heat.

ChemCam
[illegible]

Wheels
Six wheels with a 'rocker-bogie' system help the Curiosity balance over uneven terrain, while cleats on the tread provide grip.

MEDLI
[illegible]

The statistics…

Curiosity rover

Cost: $2.5bn (£1.6bn)

Weight: 900kg (1,984lb)

Scientific payload: 57kg (125lb)

Size: 3 x 2.7 x 2.2m (10 x 9 x 7ft)

Arm reach: 2.2m (7ft)

Wheels: 6

Top speed: 144m/ph (450fph)

Power: Plutonium RTG

HEAD 2 HEAD MARS ROVER LIFETIMES

Sojourner
The Mars Pathfinder rover landed on 4 July 1997 and communications were lost just a couple of months later on 27 September 1997.

Spirit
The first of the two Mars Exploration Rovers landed on the Red Planet on 4 January 2004 and its final communication was received on 22 March 2010.

Opportunity
Spirit's twin has been on Mars since 25 January 2004 and, amazingly, is still going, eight years on, having survived through five Martian winters.

DID YOU KNOW? *In Victorian times, it was widely believed that life flourished on Mars*

The WEB
The body of the rover is called the warm electronics box (WEB), and contains its computer and other fragile equipment.

The computer
Inside, the computer, the brains of the Curiosity, regulates systems, calculates movement and enables communications with mission control.

SAM
[illegible]

Curiosity's first drive

After landing, but just before it takes its first 'steps', engineers need to run some important tests on the rover. Of primary concern is its initial footing and the terrain, which must be assessed so that the Curiosity can be moved safely away from the landing site. Then the MSL will go through a start-up sequence that includes measuring the air temperature, testing communications, unfolding the mast that carries the navigation camera, shooting images of its immediate surroundings and helping mission control pinpoint its precise location. Only then will Curiosity make its first foray across Mars.

REMS
[illegible]

Surviving winter on Mars

Martian winters are more brutal than even the coldest place on Earth. It can plummet as low as -143 degrees Celsius (-225 degrees Fahrenheit) in the negligible atmosphere of the polar ice caps. It gets so cold that the carbon gas in the atmosphere freezes at certain times in the Martian calendar, causing the atmospheric pressure to plunge. The main problem with Spirit and Opportunity wasn't the cold, though – it was that they were solar-powered, which meant that during the dark periods they went into a state of hibernation with little or no activity. However, Curiosity has an independent power source, so it won't have to work around the same constraints.


The coldest recorded temperature on Earth is -89°C (-129°F), while on Mars can get as low as -143°C (-225°F)

Hazcam
Two cameras – one on the front and another on the rear – capture three-dimensional images that help avoid crashes.

RAD
[illegible]

"Curiosity's capable of examining scientifically interesting sites from a distance then moving to them"

Life – but not as we know it…

Curiosity is a very versatile machine. It can measure the atmospheric pressure, humidity, wind speed and UV levels on Mars, detect radiation levels dangerous to humans, scan for minerals and gases trapped beneath the surface and take many gigabytes' worth of images and video.

The rover is very tactile too, capable of examining scientifically interesting sites from a distance and then moving to them, scooping up soil samples, collecting and sifting through Martian rock, drilling to remove samples with a mechanical arm, blasting the surface of boulders with a powerful laser and examining the plasma that they emit. It can then analyse everything it has zapped, drilled, scooped and sucked up in a portable laboratory housed in its body that could rival a university chemistry lab. We know it can collect masses of useful scientific data, but what can we expect to find, and what can we conclude from that information?

NASA's major goal in all the experiments that the MSL will conduct in its Martian year is to assess whether the processes on Mars indicate a planet that was ever capable of supporting life. A lifeless planet (or moon, such as Earth's) that proves completely inert for billions of years could never have harboured life, for example. We know Mars has been subject to geological and atmospheric changes for millions of years, so the MSL is there to see what other changes the planet has experienced and to examine the finer details. Among other things, it will analyse sedimentary rock to see whether water was once present and look for evidence of ancient microbes, the simplest of life forms, in the rocks that will leave behind geological signatures, like ancient organisms that formed calcium carbonate (chalk) on Earth.

From a broader perspective, we're very subjective judges of the conditions that lead to life – we only know for sure that the conditions on Earth led to life here. So one of the goals of the MSL is to build up a new picture of how other organisms might evolve, to help in the search for potential life around the cosmos. From MSL and Mars, NASA has other targets in the long term. Within our own Solar System, these include Titan, Europa and Enceladus, the frigid moons that orbit Saturn and Jupiter. Then maybe in the very distant future, we'll be able to send a space laboratory beyond our own planetary system to those exoplanets with life potential, perhaps discovering the conditions for life somewhere else in the universe, whatever form it may take.

Mars deconstructed

[illegible]

Surface
Mars is very rocky and iron-rich, resulting in a high iron oxide soil content that gives the planet its [illegible]

Crust
[illegible]

Gravity
[illegible] that of our planet's.

Poles
Like Earth, Mars has north and south polar regions, which are covered in frozen water.

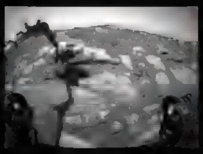
Missions to Mars

Past, present and future 'soft' landings on Mars

1971
The Russian lander Mars 2 touches down safely, then promptly stops transmitting.

1976
Viking 1 is a complete success for NASA, lasting for over six Earth years.

1997
NASA's Mars Pathfinder successfully lands its 10.5kg (23lb) rover, Sojourner.



2004
Mars Exploration Rovers A and B, Spirit and Opportunity, land three weeks apart.

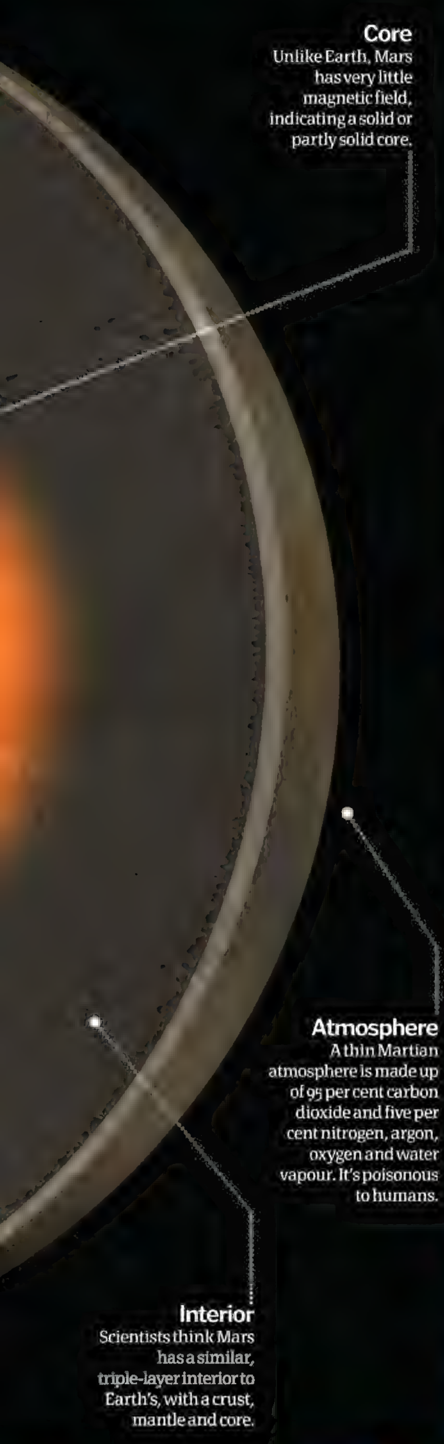
2008
The most recent spacecraft to successfully land on Mars is the Phoenix lander.

STRANGE BUT TRUE
COLONY ON MARS?

TERRAFORMING MARS

Scientists believe colonisation of Mars is possible. The atmosphere would need thickening and temperature raising, but this could be done using a giant orbital mirror to melt the ice caps, releasing carbon dioxide gas and triggering a greenhouse effect.

DID YOU KNOW? *Mars is much smaller than Earth, but because it has no oceans, it has about the same land surface area*



Core
Unlike Earth, Mars has very little magnetic field, indicating a solid or partly solid core.

Atmosphere
A thin Martian atmosphere is made up of 95 per cent carbon dioxide and five per cent nitrogen, argon, oxygen and water vapour. It's poisonous to humans.

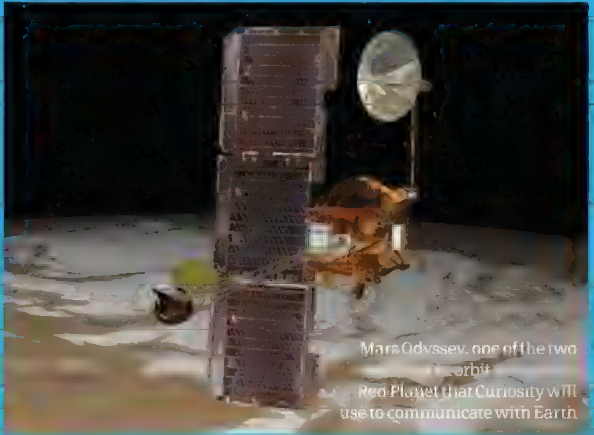
Interior
Scientists think Mars has a similar, triple-layer interior to Earth's, with a crust, mantle and core.

Clean machine

Keeping any scene of investigation clear of external influence is vital to a scientist. NASA is searching for the potential for Martian life, so minimising any terrestrial contamination is a major priority for the MSL. Contaminants are measured as 'spores' and might include Earth bacteria, dust and other synthetic materials. Throughout the project, NASA has gone to great lengths to keep the MSL as clean as possible, resulting in a spore count less than half the maximum set by NASA Planetary Protection Office regulations.

Keeping in touch

To receive commands and send data back to NASA, Curiosity will make use of terrestrial and Martian infrastructures. On Earth, three enormous antenna arrays [illegible] (230 feet) in diameter make up the DSN (Deep Space Network). These are based in the USA, Spain and Australia. Communicating directly with the DSN can be costly in terms of Curiosity's energy consumption and, due to the orbital position of Mars relative to the Earth and the Sun, it might not always be possible. Therefore sometimes Curiosity will uplink to two satellites orbiting Mars: the Mars Odyssey and the Mars [illegible] between 257 and 400 kilometres (160 and 250 miles) above the surface of the Red Planet, so are not only costing Curiosity less energy to send messages to, but they have Earth in their field of view for a lot longer, granting a larger window of communication.



Mars Odyssey, one of the two [illegible] orbit [illegible] Red Planet that Curiosity will use to communicate with Earth

Interview
John Grotzinger
– Project scientist

A key member of the MSL science team offers some first-hand insight

How It Works: First, what does your role as project scientist on the MSL involve?

John Grotzinger: Probably the best way to think about it is like being the chief scientist. What that means is that we've got the rover, with all its capabilities and all the science instruments, and nine principal investigators who were responsible for building it and developing those instruments, calibrating them and establishing protocols and procedures for how we're going to operate them when we land on Mars. My responsibility is to co-ordinate all this interaction and oversee the science team of 300-plus members.

HIW: Your area of expertise is ancient surface processes on Earth and Mars – can you tell us why this was so relevant to this project?

JG: Basically, since the primary objective for the mission is the search for habitable environments on Mars – and the emphasis is strongly in the area of ancient Mars, which is why we chose the landing site – it's kind of exactly what I do on Earth. As a geobiologist, before I got involved in Mars projects, we head off into a particular field area that we select in advance, usually involving some of the oldest rocks on Earth. Then we set up our equipment, make maps and collect samples that we bring back to the lab for analysis.

HIW: How do you investigate possible life?

JG: We borrow quite heavily from these [geobiology] principles and use them for our guidance. The search for a habitable environment involves looking for evidence of an aqueous environment because water is important for all microbes. You're often trying to establish some source of energy that, if the microbes had been there, would have been used for metabolism. Then you're looking for carbon because this is a building block for life as we know it. So you take those elements as the key ingredients along with some other 'proper' elements like nitrogen, hydrogen, oxygen, sulphur and phosphorus. Then you're looking for the geological context that can present those [such as a mass of layered rock]. We hope that, as we work our way through the layers at Mount Sharp in Gale Crater we'll [uncover] the physical and chemical properties that tell us about what kind of ancient environment this once was.

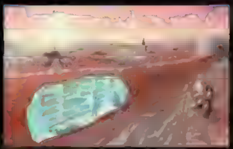
Visit our website to read the entire interview.

2012
The Curiosity rover is set to touch down on Mars on 6 August.

2014
Finland's MetNet plans to initiate a multi-lander network.

2016
The ESA will use the Trace Gas Orbiter (TGO) to place a lander on Mars.

2018
As part of the same ESA ExoMars project, Russia plans to deploy a rover.

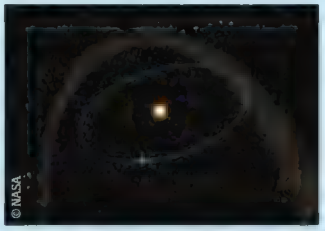


2023
Mars One is an ambitious private project that aims to establish a human colony on Mars.

"A meteor shower is a group of meteors that originate from the same source"

The Leonids

While not the most consistent of meteor showers, the Leonids can be one of the most dynamic spectacles in an astronomer's calendar. They're a product of the comet Tempel-Tuttle, which has a radius of around 1.8 kilometres (1.1 miles) and has a 33-year cycle. The comet itself is fairly unremarkable compared to the likes of Halley's or Hale-Bopp, however it leaves behind a dense stream of debris that results in a meteor shower rate that can reach as many as 300 meteors an hour.



© NASA

Meteor showers

Why the most famous of these celestial spectacles are an annual event

Meteors enter the Earth's atmosphere all the time. Spend a little time looking up at the sky at night in the country or a place with similarly low light pollution and there's a good chance you'll see a 'shooting star', the result of air friction burning the meteor up. At certain times of the year astronomers can even forecast an increase in their frequency and luminosity as annual meteor showers hit our planet. So why do these occur regularly and how are scientists able to predict them?

A meteor shower is a group of meteors that originate from the same source. In the common case of one of the most prolific annual meteor shower events in the cosmic calendar, the Perseids, they're material stripped off the comet Swift-Tuttle by solar radiation as it passes the Sun. This debris then trails behind the comet, spreading out along its orbit and, if the Earth's own orbit crosses its path, then a meteor shower ensues. As it happens, both Earth and Swift-Tuttle follow very regular paths, which is why when Earth crosses Swift-Tuttle's orbit a predictable, late-July event occurs that peaks in August at around 75 meteors an hour.

Perhaps the most famous comet of them all, Halley's, has its own regular meteor shower called the Orionids that appear in October, though at a much lower rate than the Perseids.

Is the Swift-Tuttle comet a threat?

Swift-Tuttle has a 130-year orbit of the Sun and its first recorded sighting was by astronomers Lewis Swift and Horace Tuttle 150 years ago in July 1862. Astrophysicist Brian Marsden's calculations for the next perihelion (the name for any satellite's closest approach to the Sun) in 1992 were off by 17 days, which put the comet on a potential collision course with Earth in 2126. It panicked astronomers, as the comet is around 9.7 kilometres (six miles) wide, which is roughly the same size as the Chicxulub asteroid that's generally held to be the major culprit in the extinction of the dinosaurs 65 million years ago. But having traced Swift-Tuttle's orbit back 2,000 years, Marsden was able to refine his calculations to put the comet a comfortable 24 million kilometres (15 million miles) away for its next appearance. However, if the calculations play out, there *will* be a real cosmic near-miss when 3044 rolls around, as Swift-Tuttle will pass within just 1.6 million kilometres (1 million miles) of our planet.

© SPL

> "Recent studies of the Moon's chemistry revealed the surface is virtually identical to Earth's"

How was the Moon made?

Discover the cataclysmic events that led to the formation of Earth's only natural satellite

Between 363,570 and 405,410 kilometres (around 220,000-250,000 miles) from Earth is our only natural satellite, the Moon. It's very different from its mother planet: it has around one-eighth of the Earth's mass, a very thin, almost negligible atmosphere and it's completely devoid of life. Yet at the same time, it's very similar, with a distinct crust, mantle and solid iron core plus a mineral composition almost identical to Earth's volcanic geology. A coincidence? Scientists think not.

There are four theories of the Moon's creation, three of which have generally been discredited. One suggests the Moon is the result of dust coalescing during the formation of the Solar System, another that the Moon was an asteroid captured by Earth's gravity. Finally, 'fission theory' states that Earth was spinning so rapidly when it formed the molten mass split in two.

The generally accepted idea though is that around 4.5 billion years ago, when the Earth was forming, a Mars-sized planet – dubbed Theia – collided with it. It was such a cataclysmic event that the smaller planet was completely destroyed, sending its own iron into the Earth's core while throwing trillions of tons of debris from the surface into orbit. Eventually this coalesced to form the Moon.

This 'giant impact' theory ties into the creation of our Solar System about 50 million years before the Earth formed, during a period of intense asteroid bombardment that lasted for about 750 million years. This bombardment eventually settled, either colliding with early planets like Earth, being ejected from the Solar System or falling under the influence of the Sun's gravity and becoming part of the Asteroid Belt located between Mars and Jupiter.

4.5 billion years ago (BYA)
The Earth and a smaller planetary body, Theia, form in the same orbit.

4.45 BYA
Theia's orbital angle changes with its increasing mass and, after a period of many years, it collides with the Earth.

4.43 BYA
Debris thrown out into orbit by Theia begins to coalesce under its own gravity to form the Moon.

Scientific doubts

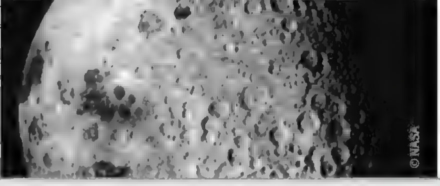
Recent studies of the Moon's chemistry by the University of Chicago revealed the surface is virtually identical to Earth's, which raised questions over the giant impact theory: if a Mars-sized planet struck our world, why is there no apparent trace of it? The impact is supposed to have been so colossal it nearly tore the Earth apart, causing it to warp into an oblong shape before rebounding under the force of its own gravity. Explanations include the possibility that Theia was a comet made of ice that could provide the required energy for the giant impact theory, but it subsequently evaporated. Scientists have also suggested that the Earth could have been spinning so fast at the time that Theia was thoroughly mixed into the Earth and the debris that eventually became the Moon. In either case, giant impact is still our most viable theory as to the creation of our lunar neighbour.

However it happened, the giant impact theory is accepted as the most likely scenario for the creation of the Moon

STRANGE BUT TRUE
LUNAR LIFE

NO MOON, NO LIFE

Without our Moon – specifically, without our large Moon – there might be no life on Earth. It has protected us over millions of years from deadly asteroids and also regulates our seasons, giving life a chance to take hold.


© NASA

DID YOU KNOW? Like a glancing shot off a snooker ball, the oblique angle Theia hit the Earth at caused our planet to spin

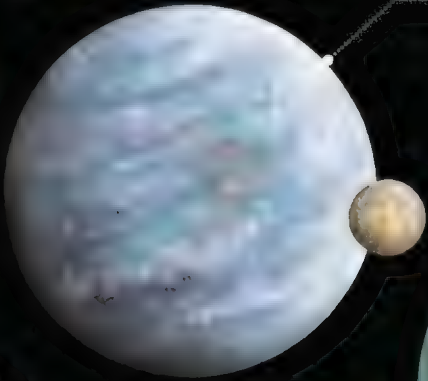
The giant impact theory

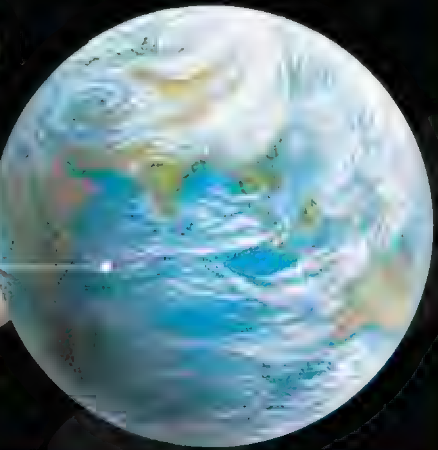
See, step by step, the various stages in our Moon's formation

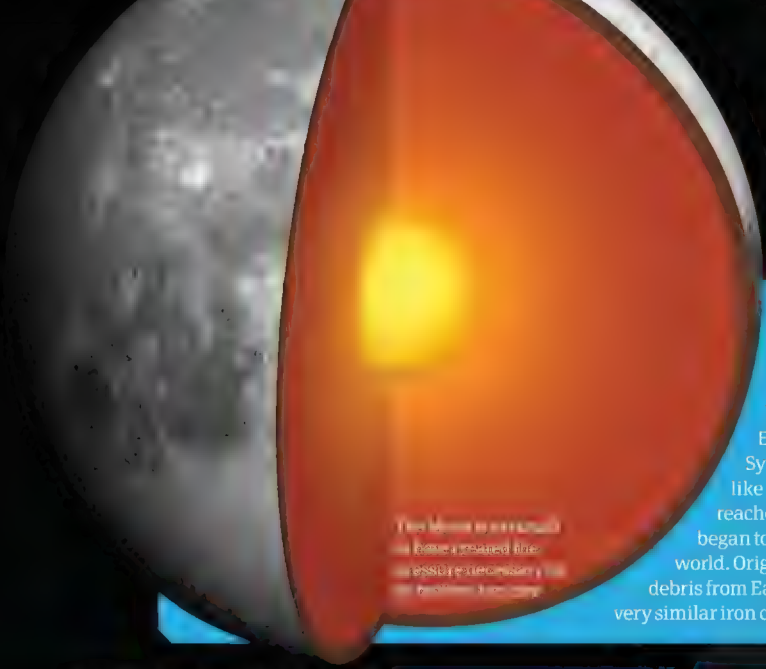

Over time, fragments of the former planet now orbiting the Earth began to reform, eventually into the rudiments of our Moon

© Alamy


3.8 BYA
The Earth's surface cools and changes from molten to a solid crust. Asteroid bombardment on the Moon rapidly slows.


2 BYA
While the building blocks of life begin to form on Earth, the Moon protects our planet from potentially deadly impactors.


Today
Tectonics has seen the topography of the Earth change, but the Moon is almost exactly as it was 2 billion years ago.



What was Theia?

The Mars-sized body that hit Earth was named after the Greek Titan who gave birth to the Moon goddess Selene. One theory is that it formed in the same orbit as Earth and, over time, coalesced with the abundance of debris in our early Solar System until it was big enough to come under the influence of its own gravity. Then, like the Earth, it began to attract asteroids that added to its bulk over time. When it reached the size of the Red Planet its orbit became unstable, its orbital angle to Earth began to increase until, eventually – just over 4.5 billion years ago, it collided with our world. Originally it was thought that the Moon was mostly the remains of Theia mixed with debris from Earth, but recent research shows that the core of the Moon and the Earth have a very similar iron composition, suggesting that they both originated from the same source.

3x © SPL

Welcome to...
ENVIRONMENT

Even in everyday moggies it's [illegible] their agility, stealth and assassin skills... but what happens when all of those talents are supersized? Also learn about an equally adept killer of the plant world – the Venus flytrap – before we look at massive marine mountains.

64 Spider webs

68 Venus flytrap

70 Oceanic ridges

LEARN MORE

BIG CATS

What makes these beautiful creatures such consummate experts in the business of killing?

The big cats aren't a single biological grouping. It's an informal term that includes the lion, tiger, jaguar and leopard (sometimes called the Great Cats), as well as the cheetah, cougar, snow leopard and clouded leopard. (The three kinds of leopard actually belong to three different genera and aren't very closely related, despite looking quite similar.) Big cats are all apex predators that hunt large mammals using their excellent camouflage to keep hidden and powerful muscles to catch and dispatch their prey.

An antelope runs on the very tips of its feet, which allows it to have a much longer stride and means it is very fast. Cats can't do this because they have claws instead of hooves, and they need to retract them to keep them sharp. To catch hoofed animals, the big cats must run with their entire spine flexing to help elongate their effective stride. It's a very energetic technique though and cats can't run fast for long distances. This in turn pushes them to be stealthy in the approach and brutal in the attack. Where a wolf will bite and retreat as it waits for its prey to bleed to death, a cougar will leap onto the back of its prey and crunch straight through the spine with a single bite.

The roar of a big cat is a sound made by the walls of the specially elongated larynx vibrating as the cat exhales, but not all big cats can do it. The cougar, cheetah and snow leopard have no roar, but they do make a variety of other noises, including chirps, screams and growls. All of the big cats are able to climb trees. Leopards are the strongest climbers; indeed, an adult male can haul a young giraffe almost six metres (20 feet) into a tree. This skill enables big cats to protect their kills from hyenas and other pack scavengers that might steal them.

It's easy to think of animals this magnificent in terms of being 'perfectly adapted', but in fact hunting large animals is incredibly difficult and all apex predators hover perpetually close to the brink. If they were anything less than brutally fit, they simply couldn't survive at all.

STOP FACTS

FELINE TRIVIA

Top acceleration

1 A cheetah can accelerate from 0-97km/h (0-60mph) in less than three seconds; that's faster than a Ferrari Enzo, a Lamborghini Gallardo or a Porsche 911 Turbo!

Mystery tuft

2 The lion is the only cat which features a furry tuft on its tail. This conceals a spike formed from fused bones at the end of the spine. Its anatomical function is still unknown.

Rise of the panther

3 Panthers aren't separate animals; it's actually just the term for an all-black mutation of a leopard or jaguar. In 1,500 years or so time, all leopards may have evolved to be completely black.

Long leapers

4 Snow leopards prefer to chase prey down a steep hill rather than on flat terrain. This often ends in a huge final leap of up to 14m (46ft), which is roughly the length of a bus.

Deafening roar

5 Lions have the loudest roar of any cat; a male lion's roar can be heard up to 8km (5mi) away. This helps to defend its territory against other males in the vicinity.

DID YOU KNOW? A leopard will eat anything from a dung beetle up to a 900kg (2,000lb) giant eland

Meet the cats...

Tiger

Type: Mammal

Diet: Carnivore (eg wild boar, water buffalo)

Life span in the wild: 20-26 years

Weight: 240kg (530lb)

Height: 1m (3.2ft)

Length: 3m (9.6ft)

Able to roar?: Yes

Leopard

Type: Mammal

Diet: Carnivore (eg Thomson's gazelle, monkeys)

Life span in the wild: 18-20 years

Weight: 60kg (132lb)

Height: 0.65m (2.1ft)

Length: 2.1m (6.8ft)

Able to roar?: Yes

Cougar

Type: Mammal

Diet: Carnivore (eg deer, elk)

Life span in the wild: 8-10 years

Weight: 80kg (176lb)

Height: 0.75m (2.5ft)

Length: 2.4m (7.9ft)

Able to roar?: No

Clouded leopard

Type: Mammal

Diet: Carnivore (eg hog deer, brush-tailed porcupine)

Life span in the wild: 7-10 years

Weight: 18kg (40lb)

Height: 0.33m (1ft)

Length: 1.8m (5.9ft)

Able to roar?: Partially

ON THE MAP

How the big cats are globally distributed

Lions: Sub-Saharan Africa, and a single population in the Gir Forest, northwest India 🟨

Tigers: India, southeast Asia, southeast Siberia 🟧

Cheetahs: Sub-Saharan Africa, plus a small population in Iran 🟦

Cougars: West Canada, central and west USA, plus most of Central America and South America 🟥

Jaguars: Central/South America 🟦

Leopards: East/central Africa, pockets of the Indian subcontinent, southeast Asia, China 🟩

Snow leopards: Hindu Kush, Himalayas, Altai Mountains and Khangai Mountains 🟪

Clouded leopards: Southeast Asia, Nepal 🟦

Snow leopard

Type: Mammal

Diet: Carnivore (eg goats, ibex)

Life span in the wild: 15-18 years

Weight: 41kg (90lb)

Height: 0.6m (2ft)

Length: 1.9m (6.2ft)

Able to roar?: No

Jaguar

Type: Mammal

Diet: Carnivore (eg caimans, capybaras)

Life span in the wild: 12-15 years

Weight: 75kg (165lb)

Height: 0.7m (2.2ft)

Length: 2.2m (7.2ft)

Able to roar?: Yes

Cheetah

Type: Mammal

Diet: Carnivore (eg Thomson's gazelle, impala)

Life span in the wild: 12-14 years

Weight: 55kg (120lb)

Height: 0.8m (2.6ft)

Length: 1.3m (4.3ft)

Able to roar?: No

Lion

Type: Mammal

Diet: Carnivore (eg wildebeest, zebra)

Life span in the wild: 10-14 years

Weight: 200kg (440lb)

Height: 1.2m (3.9ft)

Length: 2.2m (7.2ft)

Able to roar?: Yes

> "The biggest threats to big cats are habitat loss due to human expansion and poaching"

Purr-fect predators

Want to kill something three times your size? Here's what you need...

Markings
Stripes, spots and a contrasting light belly help to break up the animal's outline.

Flexible spine
Acts as a spring when pouncing and increases the effective stride length by flexing whe[illegible]

Ears
Independently movable to locate prey. White spots on the back are used to signal to other cats.

Tail
Accounts for a third of body length. Used for balance and as a rudder when changing direction at [illegible]

Forward-facing eyes
Binocular vision for accurate distance and speed perception. The reflective tapetum lucidum layer behind the retina gives excellent night vision.

Vomeronasal organ
[illegible] roof of the mouth has special receptors for detecting pheromones. Cats 'grimacing' are 'smelling' with their vomeronasal, or Jacobson's, organ.

Whiskers
Whiskers swivel forwards when striking prey to provide accurate touch sensitivity when the cat [illegible] close to see.

Incisors
The [illegible] teeth are used to puncture skulls, sever spines and crush windpipes.

Retractable claws
Most cats pull the claws in to keep them sharp when running. Cheetahs, in contrast, leave them out for extra traction.

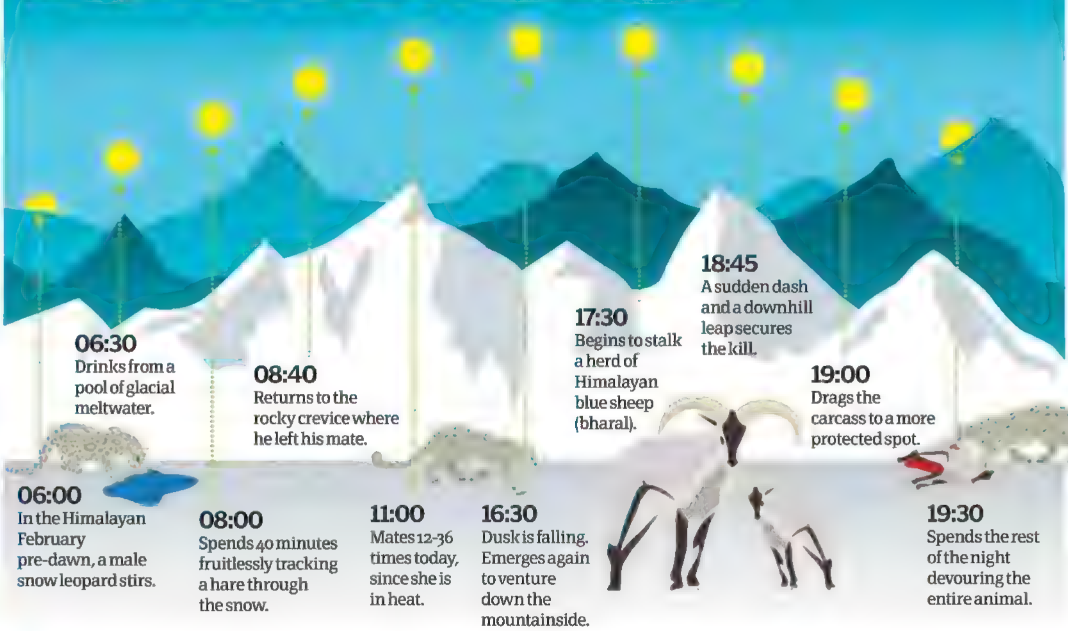
Threats to the big cats

Top carnivores are inherently vulnerable species. They require large home ranges and reproduce relatively slowly. Lions, leopards and cheetahs all suffer high infant mortality from other predators – indeed, up to 90 per cent of cheetah cubs are lost. Cheetahs also have very low genetic variability, possibly due to an extreme population bottleneck thousands of years ago, leading to birth defects as a result of inbreeding; captive breeding schemes have had very limited success. The biggest threats to big cats, though, are habitat loss due to human expansion and poaching. Although most cats have a wide geographic distribution, human development has fragmented these ranges into pockets, each of which may be too small for them to flourish in the long term.

Feuding families

[illegible]

A day in the life of a snow leopard



06:00
In the Himalayan February pre-dawn, a male snow leopard stirs.

06:30
Drinks from a pool of glacial meltwater.

08:00
Spends 40 minutes fruitlessly tracking a hare through the snow.

08:40
Returns to the rocky crevice where he left his mate.

11:00
Mates 12-36 times today, since she is in heat.

16:30
Dusk is falling. Emerges again to venture down the mountainside.

17:30
Begins to stalk a herd of Himalayan blue sheep (bharal).

18:45
A sudden dash and a downhill leap secures the kill.

19:00
Drags the carcass to a more protected spot.

19:30
Spends the rest of the night devouring the entire animal.

RECORD BREAKERS
CAT ALIASES

40+

ANIMAL WITH THE MOST NAMES

The cougar is the animal with the most folk names. These include catamount, ghost cat, puma, shadow cat, mountain lion, deer tiger, silver lion, devil cat and catawampus.

DID YOU KNOW? *If you shave a tiger of its fur the skin beneath will still be stripy*

Hunting techniques

Big cats generally hunt between sunset and dawn. They are ambush predators that move silently through dense undergrowth using their excellent vision and hearing to spot their prey before their prey spots them. Although they are all incredible sprinters, big cats lack stamina. A cheetah may exhaust itself so badly in a 60-second dash that it needs half an hour to recover and most cats will give up if they cannot run down their quarry in 30 seconds. Accordingly, they always attack from a position of advantage, leaping from cover or a tree branch, etc. Tigers will even launch attacks from the riverbank into the water and are strong enough swimmers to take on crocodiles.

Strangulation

The most common attack technique, used by all big cats, is to lunge at the neck and clamp down on the windpipe with powerful jaws. This cuts off the air supply and prey that is already out of breath from the chase quickly loses consciousness.

Asphyxiation

Another way to achieve the same result is to take a wide bite and clamp over the victim's mouth and nostrils, so it can't breathe. Lions and occasionally leopards will use this technique on antelope, but it isn't suitable for larger prey like zebra.

Neck breaking

The largest cats can leap on the back of an animal and bite right through its neck, severing the spine. This paralyses the victim instantly and ends the struggle, but it requires tremendous bite force. Lions, tigers and cougars all use this method.

Artery slicing

In the chaos of the final lunge, a cat may miss the windpipe of its prey and instead slice open the carotid artery. This is a slightly slower kill but it still gets the job done, as the victim will bleed to death.

The paw swipe

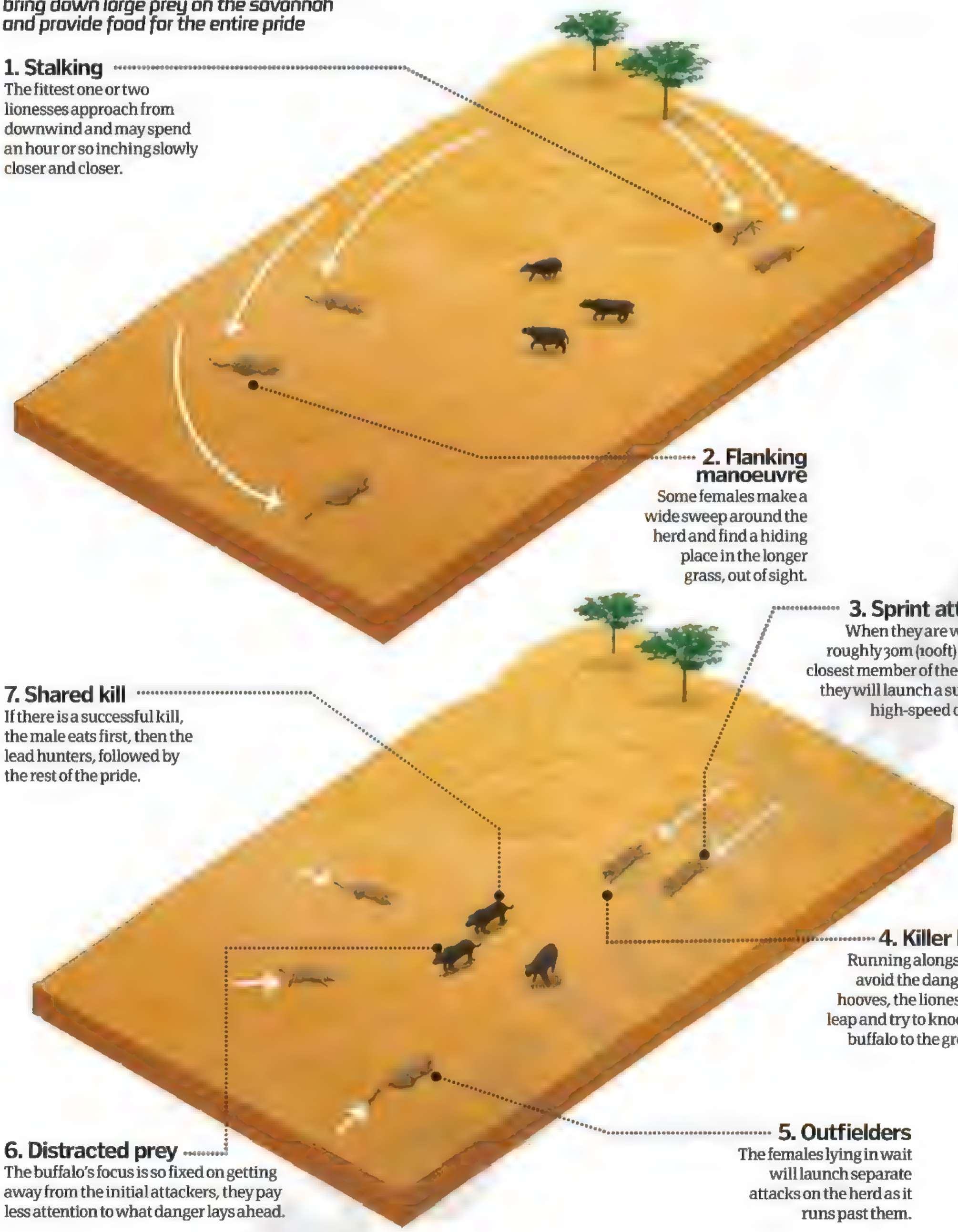
Lions and tigers are so strong that they can kill merely with a swipe of their paws. Tigers in particular have been witnessed swiping at adult domestic cattle with enough force to shatter the skull.

Skull piercing

The jaguar has the strongest bite of any cat – twice as powerful as the much larger lion. This may have evolved to enable them to bite through the shells of turtles, but jaguars also use it for a unique finishing move: their canine teeth can puncture an animal's skull and pierce the brain.

How lions hunt

Lionesses work as a team to efficiently bring down large prey on the savannah and provide food for the entire pride



1. Stalking
The fittest one or two lionesses approach from downwind and may spend an hour or so inching slowly closer and closer.

2. Flanking manoeuvre
Some females make a wide sweep around the herd and find a hiding place in the longer grass, out of sight.

3. Sprint attack
When they are within roughly 30m (100ft) of the closest member of the herd, they will launch a sudden high-speed chase.

4. Killer leap
Running alongside to avoid the dangerous hooves, the lioness will leap and try to knock the buffalo to the ground.

5. Outfielders
The females lying in wait will launch separate attacks on the herd as it runs past them.

6. Distracted prey
The buffalo's focus is so fixed on getting away from the initial attackers, they pay less attention to what danger lays ahead.

7. Shared kill
If there is a successful kill, the male eats first, then the lead hunters, followed by the rest of the pride.

What's on the menu?

Hunting big game is an erratic profession. Cheetahs can generally manage a 50 per cent success rate but a tiger may only kill its prey one time in every 20 attempts. Consequently, they need to be able to make the most of each kill. Lions will eat 30 kilograms (66 pounds) of meat in one sitting, while jaguars can eat 25 kilograms (55 pounds) – a third of their body weight; that is the equivalent of you eating over a hundred Big Macs in one sitting! After a meal like that, lions, tigers, cougars and snow leopards can go for up to two weeks without eating again. Big cats are all quite opportunistic hunters. As well as their favoured prey of medium to large herd animals, they will eat monkeys, rodents, lizards, porcupines and birds' eggs. Many cats – especially the forest dwellers – will also eat insects and a small amount of fruit and vegetation.

"With the main frame lines in position, the spider begins to attach radial threads"

How does a spider construct its web?


The spinnerets in action, here being used to cocoon a victim

Learn how arachnids create their spiral orb webs in which to ensnare prey

Building a spider web is a very complex process. Referring to the stages below, first the spider (at point A) dangles a length of sticky silk, which can be carried in the air until it sticks to an anchor point, such as a branch (see point B). Once the silk is attached to point B, the spider pulls it taut and fixes the original end to anchor point A, creating the 'bridge thread' (red).

Now the spider fixes a second strand (blue) to point A and spins this while crossing the bridge. This thread is looser than the first and droops below the bridge thread. At point B the spider attaches this strand but doesn't pull it taut.

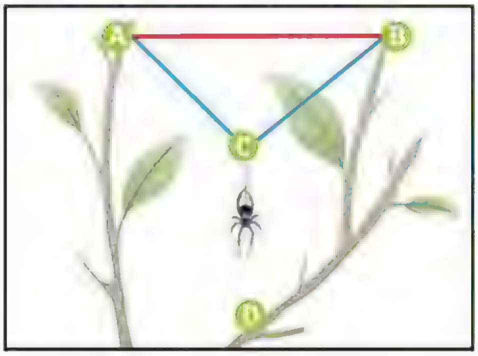
Next the spider travels back halfway along the now anchored loose thread (to point C; the web centre); the weight of the spider bows the thread into a V-shape, and from the bottom of the 'V', the spider attaches a third thread, which is spun as the arachnid descends to another branch (anchor point D). This turns the V-shape into a Y-shape, and creates another integral pathway. The spider continues to create more of these structural strands until a basic framework is in place.

With the main frame lines in position, the spider adds radial threads from the centre to surrounding vegetation, much like the spokes of a wheel. These form the non-stick paths upon which the creature can safely navigate its trap.

Next the spider creates a silk spiral across the radial lines from the inside out. Using this as a template, it repeats this stage, except this time the threads are coated in bug-catching adhesive.

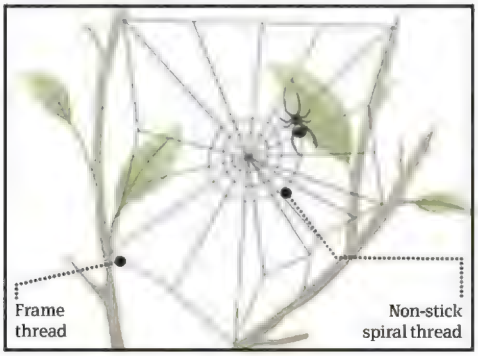
Now all the spider needs to do is position itself at the centre of its trap and wait. These creatures are very sensitive to vibrations and, quick as a flash, the spider can expertly traverse its web to confront a haplessly entangled victim.

Stage 1: Creating a framework

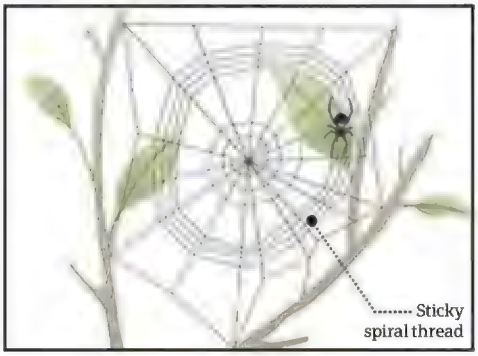


Stage 2: The orb takes shape

Stage 3: The spiral template



Stage 4: Setting the trap



The science of silk

Spider silk is made of proteins called fibroins. It's very strong – in fact, weight for weight it's tougher than steel – yet also extremely elastic. These two characteristics, together, make for one unique substance in nature that the world's greatest material scientists have been trying to re-create artificially.

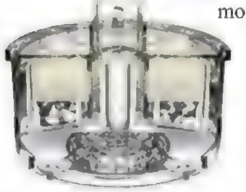
Silk is secreted as a liquid from the spider by the spinnerets, which are special glands located in the tip of the arachnid's abdomen. Upon contact with air the liquid instantly hardens to become a fine but strong silk. As the material is produced, the spider pulls it into long, thin threads using its legs.

The reason the spider itself does not become caught in its own web is that, first, it knows which sticky strands to avoid and, second, the adhesive hardens if the unwitting victim makes a sudden movement, but not with the gentle, considered movements of the spider.

"For people who want a home aquarium, but think it's too much work"

At last, an aquarium for busy people. biOrbs have built-in lighting and simple filtration that really works. The filter cartridges are easy to change and it only takes a few seconds.

A revealing truth about aquarium filters
Many traditional aquariums have a filter on the side or at the top, but guess what - fish waste sinks. biOrbs have a filter hidden at the bottom of the aquarium. Put simply, a biOrb filter works where there is most waste to filter.



Inside the patented filter. Air driven filtration creates vigorous water flow. This maintains oxygen saturation. Circular water flow collects fish waste and traps it in the easy-to-change cartridge.

Why they're made from acrylic, not glass
Acrylic is ten times stronger than glass. Why's that so important? Just ask anyone who's broken a glass aquarium and flooded their home.

Did you know it's clearer?
Acrylic has a transparency rate of 93% but glass only allows 70% of light to pass through. With a biOrb it's been said that *"it's like watching your fish in high definition"*.

All you'll need to get started is included
Light, Pump, Filter. You'll also get step-by-step, easy to follow instructions. Just sit back and enjoy the magic of keeping fish. What's more, every biOrb is backed by our no-quibble 12 month guarantee.

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Over a million people now keep fish the easy way with a biOrb. If you ever thought that an aquarium would be nice to have, but didn't like the idea of all the work, then a biOrb is for you. They're designed to be simple to set up and easy to look after.

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> "They are eukaryotic, which means they contain a nucleus – a structure that acts as the cell's 'brain'"

Plant cell anatomy explained

Discover how these tiny living structures function

Without the plant kingdom, life on Earth would be a very different prospect. This huge and diverse group of living organisms not only nourishes the vast majority of animal life with tasty, nutritious roughage, but it also replenishes our atmosphere with enough oxygen to keep us living and breathing. Quite simply, life on Earth depends on plants.

There are a number of characteristics that make all living things 'alive'. For instance, they require food for growth and development; they respond and adapt to their surrounding environments; they have a life cycle of growth, reproduction and death; and, importantly, they contain cells.

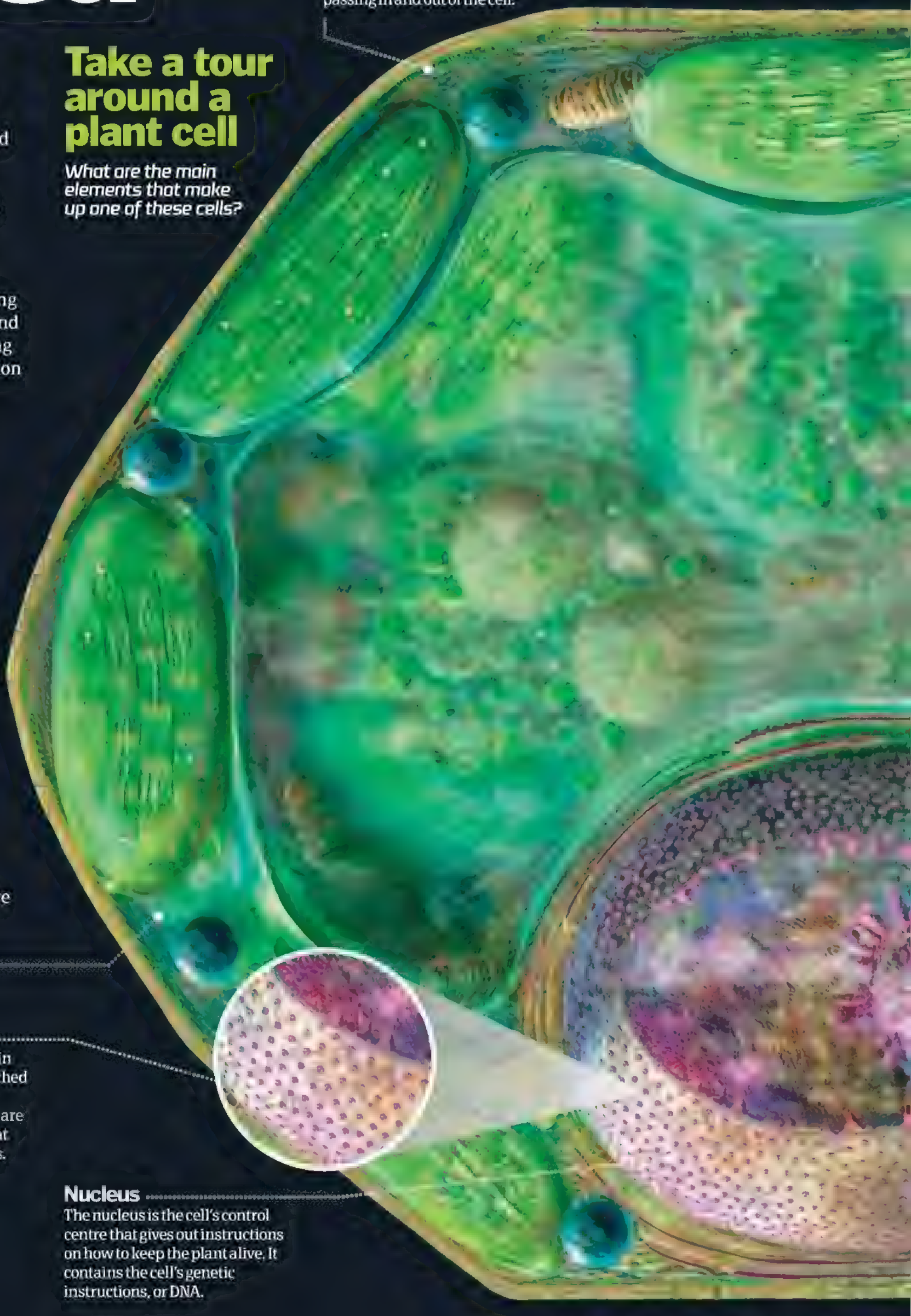
Discovered by Robert Hooke in the 1650s, plant cells are the building blocks of all plant life. Just like animal cells, they are eukaryotic, which means they contain a nucleus – a structure that acts as the cell's 'brain' or command centre. Found in the nucleus is the plant's genetic information, which is used to inform the rest of the cell which functions to carry out.

Everything inside the cell is contained within a thin, semi-permeable lining called the plasma membrane. Inside this membrane is a sea of cytoplasm, a gelatinous substance in which all the other parts of the plant cell are found – most of which have specialised functions. These 'expert' structures have dedicated roles and are known as organelles, or 'mini organs'. Surrounding the plasma membrane is a rigid outer cell wall made from a fibrous substance called cellulose.

Another characteristic of a plant cell is its large vacuole. This is an area filled with fluid and gas and it accounts for most of a cell's mass. The vacuole swells with fluid to help maintain a cell's shape. The tough cell wall is strong enough to withstand this increased pressure and ensures this organic 'balloon' doesn't burst.

Take a tour around a plant cell

What are the main elements that make up one of these cells?



Cell membrane
The cell, or plasma, membrane is the layer that covers the cytoplasm and separates the cell from its external environment. It controls all substances passing in and out of the cell.

Cytoplasm
Cytoplasm is the jelly-like substance inside the cell in which energy-producing chemical reactions occur. The cytoplasm fills the space between the cell membrane and the nucleus.

Ribosome
Found either floating in the cytoplasm or attached to the endoplasmic reticulum, ribosomes are the tiny structures that manufacture proteins.

Nucleus
The nucleus is the cell's control centre that gives out instructions on how to keep the plant alive. It contains the cell's genetic instructions, or DNA.

5 TOP FACTS PLANT CELLS

Discovery

1 17th-century scientist Robert Hooke was the first to study plant cells with a microscope. In his book *Micrographia* he described his observations and coined the term 'cell'.

Plant or animal?

2 Though plant and animal DNA molecules are chemically similar, the differences in the way the nucleotides are arranged determine whether an organism is animal or plant.

Food factory

3 Sunlight turns CO_2 and H_2O into glucose. When photons from the Sun hit the chlorophyll in a plant, electrons are excited. Chloroplasts then transfer this energy to a plant's food-making organelles.

Free lunch

4 While most plants can create their own food from the elements, some parasitic plants do not have chlorophyll to photosynthesise. These species depend on a host to obtain glucose and other nutrients.

Eukaryotic vs prokaryotic

5 Plant cells have a nucleus, which makes them eukaryotic (the same as fungi). Cells that do not have a nucleus are known as prokaryotic and include single-celled organisms like bacteria.

DID YOU KNOW? While all other animal cells are eukaryotic, red blood cells are erythrocytic as they do not contain a nucleus

Plant cells vs animal cells

As we've mentioned already, there are many similarities between plant and animal cells. However, there are also several key differences. For example, animal cells are bigger and less regular in shape and size than those of plants, which are generally regimented in appearance. Take a look at the main structures in a plant cell that are absent in animal cells.

Cell wall

While both animal and plant cells have a thin cell membrane that controls what goes in and out, plants differ in that they also have a cell wall made of cellulose. This rigid outer wall enables the plant to hold a lot of moisture under pressure without popping, while also providing essential structural integrity. The contents of an animal cell, meanwhile, are held by the cell membrane alone. Animals tend to rely on endo- and exo-skeletons for support.

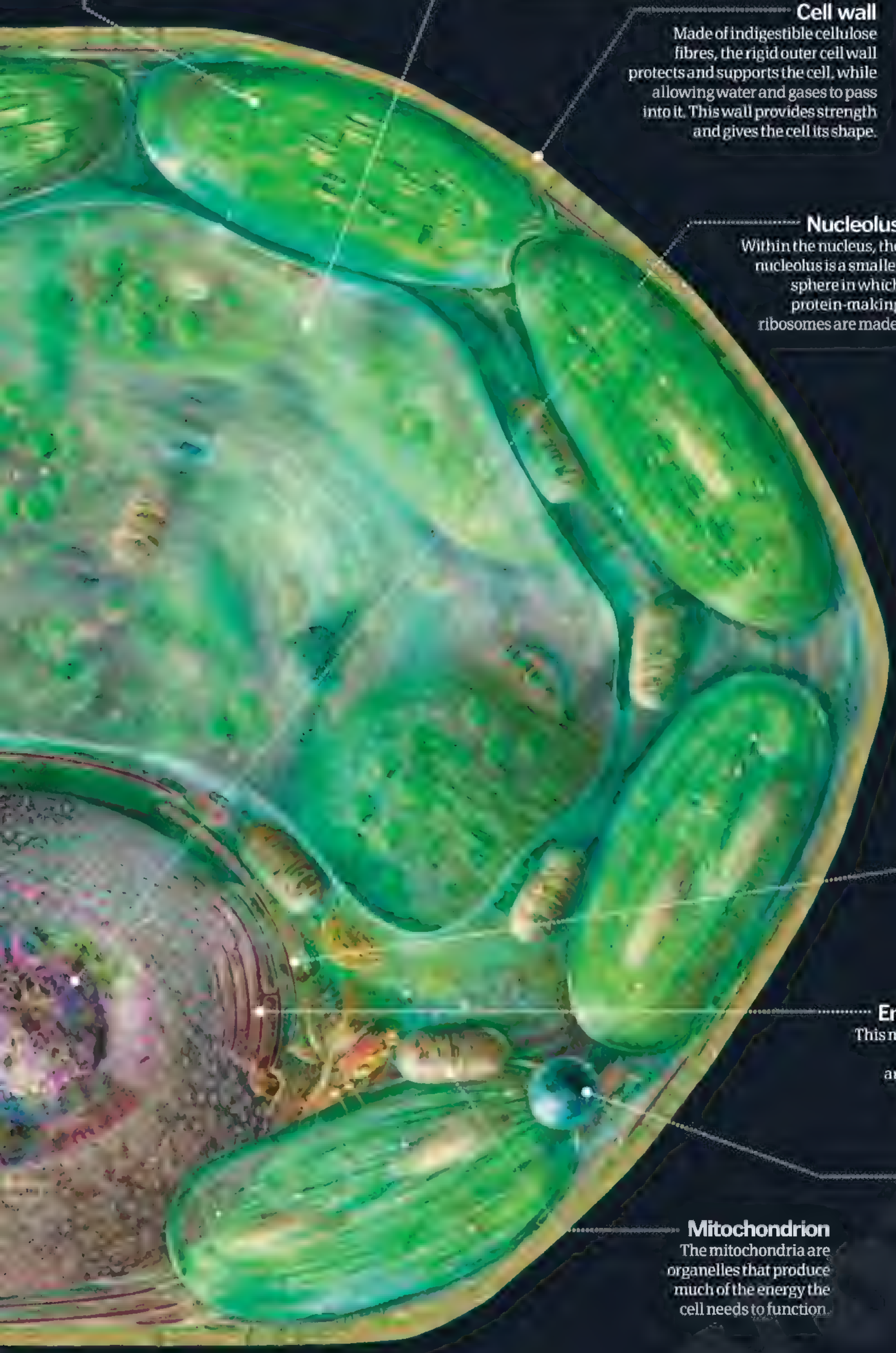
Single large vacuole

Plant cells also contain a single, extra-large vacuole, which takes up most of the space in the cell and keeps it plump and turgid. Some animal cells do contain vacuoles, but they are always much smaller and never take up this much space.

Chloroplasts

Plants manufacture their own food (glucose) from sunlight, water and carbon dioxide, but humans and animals must *absorb* food obtained from plants and other living creatures. The difference is that plant cells contain chloroplasts – the structures that contain the green, sunlight-absorbing chlorophyll pigment – in which photosynthesis can take place.

> "There are several key differences between animal and plant cells"



Chloroplast
Chloroplasts are effectively like solar panels that capture the Sun's energy and use it to make food for the plant – a process called photosynthesis. Inside a chloroplast is chlorophyll, the pigment which gives most plants their green colouring. Chlorophyll is essential for photosynthesis as it absorbs the sunlight to produce glucose.

Vacuole
The large vacuole is a kind of storage area for water and waste gases. It helps to keep the cell plump and turgid.

Cell wall
Made of indigestible cellulose fibres, the rigid outer cell wall protects and supports the cell, while allowing water and gases to pass into it. This wall provides strength and gives the cell its shape.

Nucleolus
Within the nucleus, the nucleolus is a smaller sphere in which protein-making ribosomes are made.

Golgi apparatus
Also a kind of organelle, a Golgi body processes and packages proteins ready for transport outside the cell or to other parts within the cell.

Endoplasmic reticulum
This membrane acts like a conveyor belt that transports proteins around the plant cell interior as well as outside the cell wall.

Peroxisome
Peroxisomes are the organelles that aid photosynthesis. They contain enzymes that break down toxins and remove waste from the cell.

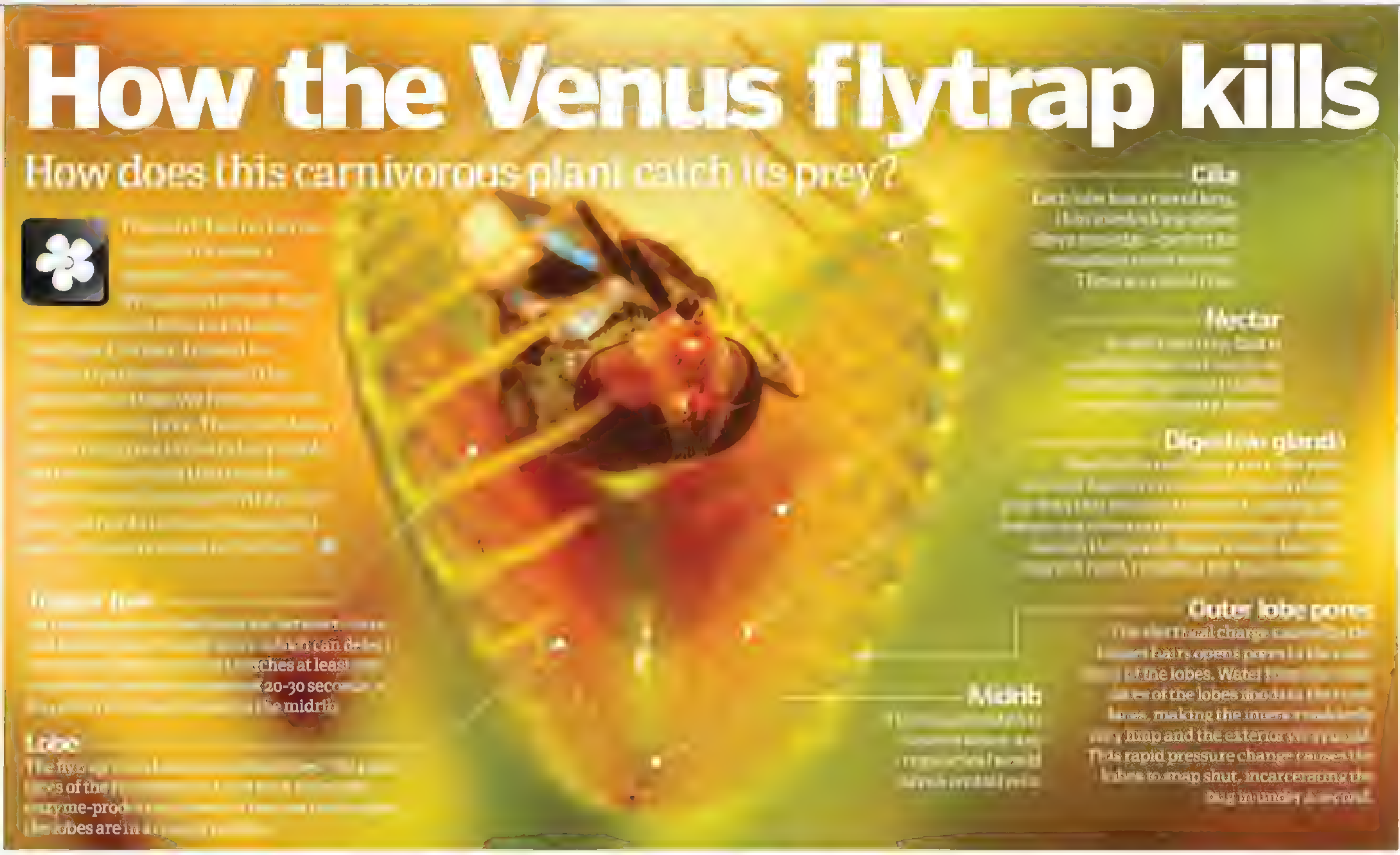
Mitochondrion
The mitochondria are organelles that produce much of the energy the cell needs to function.

© SPL

> "These predatory plants can grow in the inhospitable, nutrient-poor soils that regular plants cannot"

How the Venus flytrap kills

How does this carnivorous plant catch its prey?



[illegible]

Trigger hair

[illegible] can detect [illegible] touches at least [illegible] 20-30 seconds [illegible] the midrib

Lobe

The flytrap [illegible] faces of the [illegible] enzyme-prod[illegible] the lobes are in [illegible]

Cilia

[illegible]

Nectar

[illegible]

Digestive glands

[illegible]

Outer lobe pores

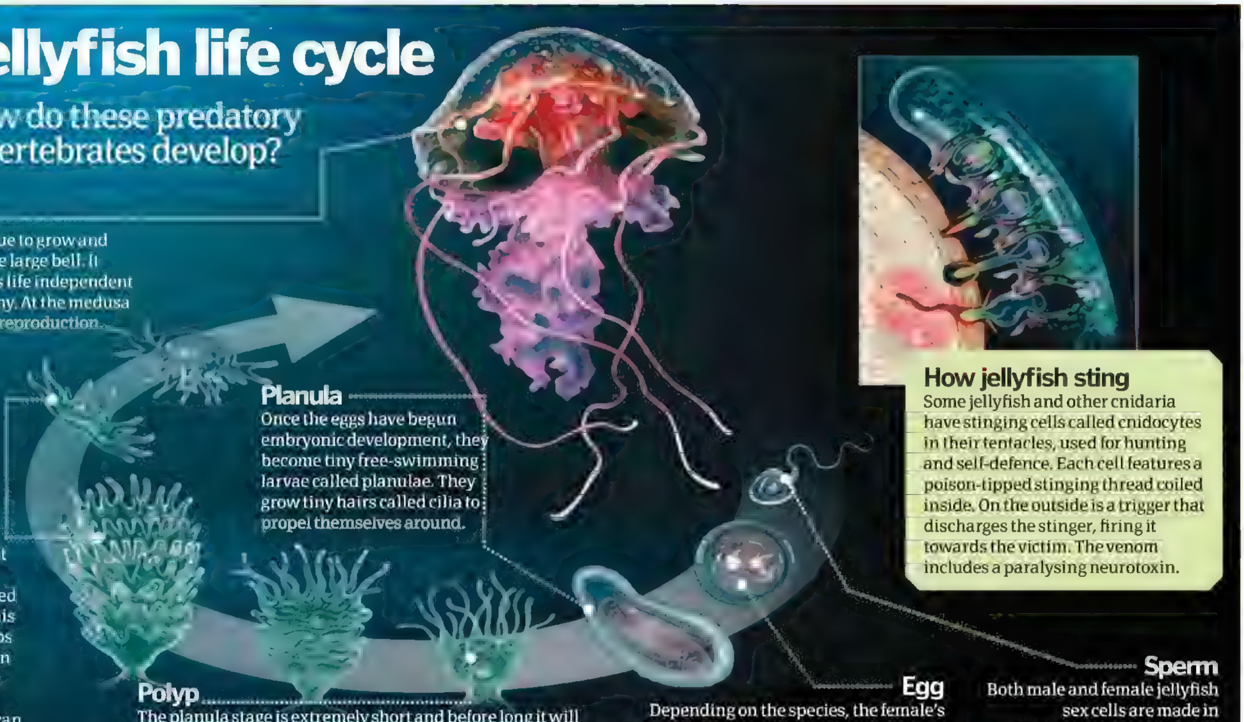
The electrical charge [illegible] trigger hairs opens pores in the [illegible] of the lobes. Water [illegible] of the lobes floods the [illegible] making the interior [illegible] limp and the exterior [illegible] This rapid pressure change causes the lobes to snap shut, incarcerating the bug in under a second.

Midrib

[illegible]

The jellyfish life cycle

How do these predatory invertebrates develop?



Medusa

The ephyrae continue to grow and develop a distinctive large bell. It spends the rest of its life independent from the polyp colony. At the medusa stage it's capable of reproduction.

Planula

Once the eggs have begun embryonic development, they become tiny free-swimming larvae called planulae. They grow tiny hairs called cilia to propel themselves around.

Growth stage

As the polyp grows, it produces clones of itself – a process called asexual budding. This new 'colony' of polyps starts to propagate on the stem of the main polyp, linked by feeding tubes. This can go on for years before the baby jellyfish (or ephyrae) detach and swim off independently.

Polyp

The planula stage is extremely short and before long it will have attached itself to a hard surface on the floor of a coastal reef. Here the planula grows a stalk with which to anchor itself to something solid like a rock. At the top of the polyp a mouth and tentacles develop for feeding and growing.

Egg

Depending on the species, the female's eggs are fertilised either by being released into the water where they encounter the sperm, or by the adult female collecting the sperm in special brooding folds.

Sperm

Both male and female jellyfish sex cells are made in reproductive organs called gonads. The male adult jellyfish produces sperm, which it releases via its mouth.

How jellyfish sting

Some jellyfish and other cnidaria have stinging cells called cnidocytes in their tentacles, used for hunting and self-defence. Each cell features a poison-tipped stinging thread coiled inside. On the outside is a trigger that discharges the stinger, firing it towards the victim. The venom includes a paralysing neurotoxin.

© SPL

5 TOP FACTS SPITFIRE F Mk.22

Very fast
The Spitfire F Mk.22 was capable of speeds in excess of 450mph, making it one of the fastest Spitfires of all time.

Missed, but not forgotten
The F Mk.22 was in fact obsolete before it even entered service, due to the advent of new jet technology.

Auxiliary use
Only 1 regular RAF squadron used the variant, but 12 auxiliary Air Force squadrons operated the type.

Very popular
Export users included Egypt and Syria, where the variant saw combat against other Spitfires!

Best got better
The penultimate Spitfire variant, the F Mk.24 differed from this variant in only its cannons and some panel details.

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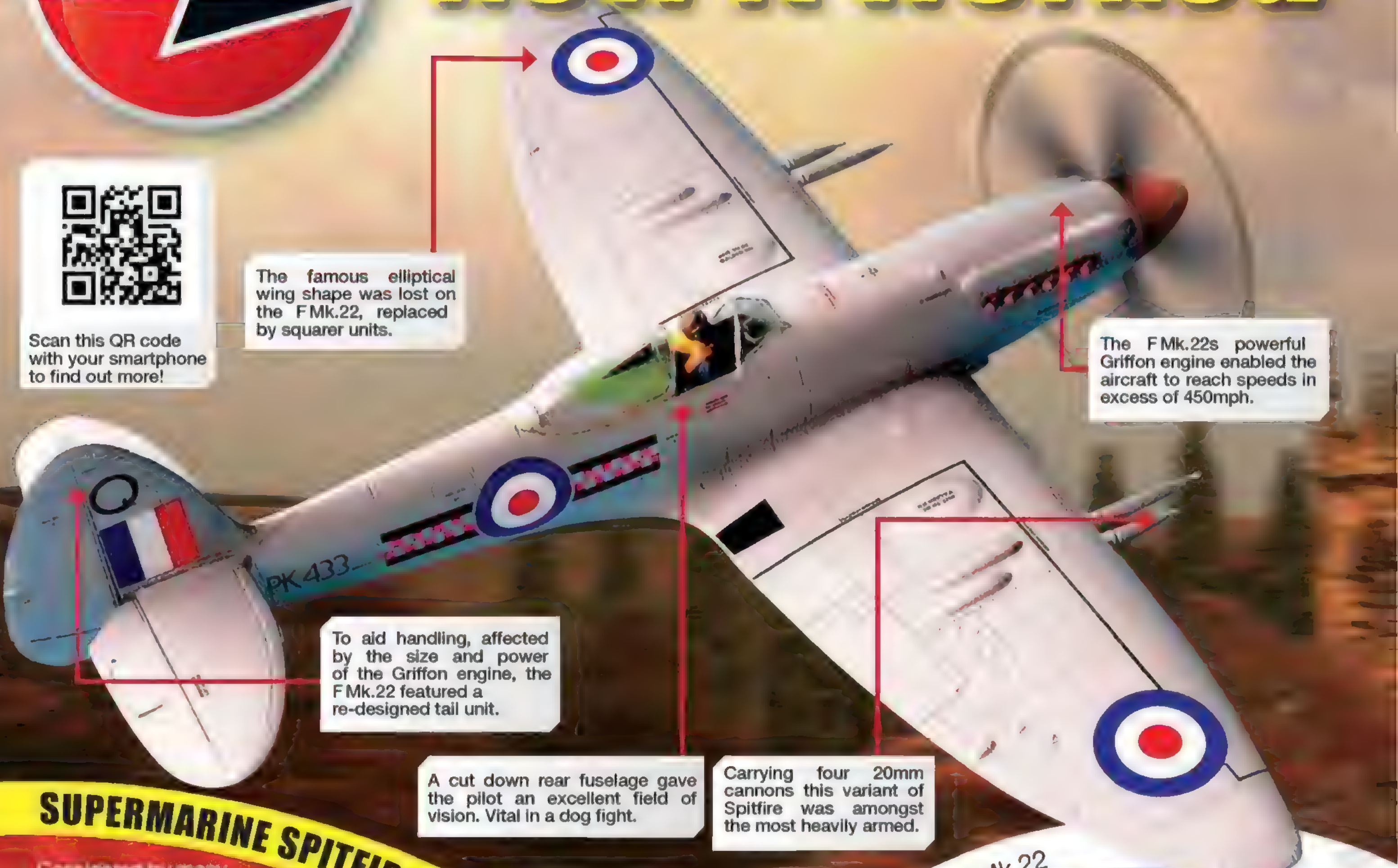
How it worked



Scan this QR code with your smartphone to find out more!

The famous elliptical wing shape was lost on the F Mk.22, replaced by squarer units.

The F Mk.22s powerful Griffon engine enabled the aircraft to reach speeds in excess of 450mph.

To aid handling, affected by the size and power of the Griffon engine, the F Mk.22 featured a re-designed tail unit.

A cut down rear fuselage gave the pilot an excellent field of vision. Vital in a dog fight.

Carrying four 20mm cannons this variant of Spitfire was amongst the most heavily armed.

SUPERMARINE SPITFIRE F Mk.22

Considered by many to be the ultimate land-based Spitfire, the F Mk.22 and its successor the F Mk.24, were the pinnacle of RJ Mitchell's original iconic design. While not the first Griffon powered Spitfire (the MkXII), nor the last in service with the RAF (the PRXIX), the F Mk.22 was the final version of the Spitfire to see the frontline operations with the RAF.

The F Mk.22 Spitfire was about as sophisticated as the piston Spitfires were to get. It differed from the final variant, the F Mk.24, in only minor respects, but used the same massive Griffon engine delivering well over 2,200hp which dictated the enlarged tail control surfaces introduced with the Mk.21. The redesigned wing was a distinctive feature of the type which performed well until eventually being outclassed by the first jet fighters.

A02033 1:72 Scale Supermarine Spitfire F Mk.22

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> "Most of the mid-Atlantic plate is underwater, but some of it is high enough to appear above sea level"

Massive marine mountains

If you thought mountain ranges were restricted to land, then think again…

The Mid-Atlantic Ridge is part of the longest mountain range in the world – these mountains just happen to be underwater. Mid-ocean ridges are a result of plate tectonics, and form due to volcanic activity in the oceanic crust. Currents in the Earth's mantle cause magma to heat up, and it is forced through weak spots in the crust. The resulting lava cools into a new layer of crust. This pushes the plates apart and the resulting formation often has a rift, or valley, in the centre where two different plates are being pushed apart. All of these mid-ocean ridges are connected around the world, totalling 80,000 kilometres (50,000 miles) or so in length.

The Mid-Atlantic Ridge by itself is around 10,000 kilometres (6,200 miles) long. It separates the North American tectonic plate (which also includes the Bahamas, Cuba, Greenland and parts of other countries) from the Eurasian tectonic plate. It also separates the South American tectonic plate from the African tectonic plate. Most of the mid-Atlantic plate is underwater, but some of it is actually high enough to appear above sea level. This includes a ridge that contains the island of Iceland, as well as a number of other islands.

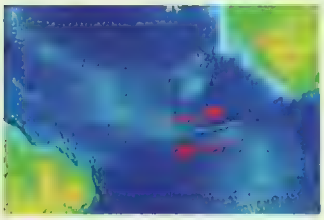
Oceanographers and researchers have thought there was a mountain range in the ocean here since the 1870s, and it was confirmed in 1925 by sonar. It wasn't until the Fifties, however, that we were able to fully understand the unique features hidden in the depths of the mid-Atlantic, and realised just how massive it really was. In addition to the islands, there are numerous deep trenches and valleys as well as extensive seismic activity, which is constantly altering the terrain.


The red boundaries show the tectonic plates that make up the Earth's crust, which are shifting and moving all the time

Mid-Atlantic Ridge key features

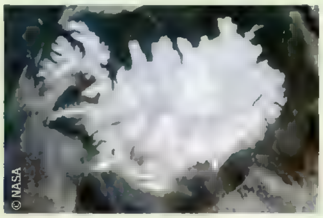
1 Romanche Trench

This trench is the third deepest in the Atlantic, and bisects the Mid-Atlantic Ridge around the equator, between Brazil and west Africa. It is about 19km (12mi) wide, 300km (186mi) long and 7.76km (4.82mi) deep. Because of its depth, it plays a key role in water circulation between the east and west Atlantic basins.



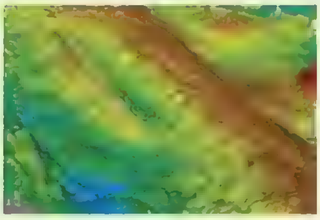
2 Iceland

The island of Iceland in the northern Atlantic Ocean is part of a sub-ridge on the Mid-Atlantic Ridge that's known as the Reykjanes Ridge; this rises 2,110m (6,923ft) from the seabed. Incidentally, Iceland is also on top of a mantle plume, a place where hot rock has risen through the mantle but isn't a part of plate tectonics.


© NASA

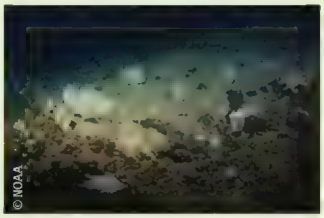
3 Deep rift valley

This valley runs the entire length of the Mid-Atlantic Ridge (approximately 10,000km/6,200mi) and serves as the boundary between the North American and the Eurasian tectonic plates that are separated by the ridge. At 1-3km (0.6-1.8mi) deep, it is similar in depth and width to the Grand Canyon.



4 Atlantis Massif

This huge dome-shaped hill is just west of the centre of the ridge. It's about 1,700m (5,500ft) high and much wider than other hills on the ocean floor. It's very smooth compared to the surrounding terrain, so it must be fairly new (in geological terms), but oceanographers are still trying to determine how it formed.


© NOAA

THE STATS
MID-ATLANTIC RIDGE

LENGTH: 10,000km (6,213mi)

NUMBER OF ISLANDS: 6

SPREADING RATE PER YEAR: 2.5cm (1in)

BELOW SEA LEVEL: 2.5km (1.5mi)

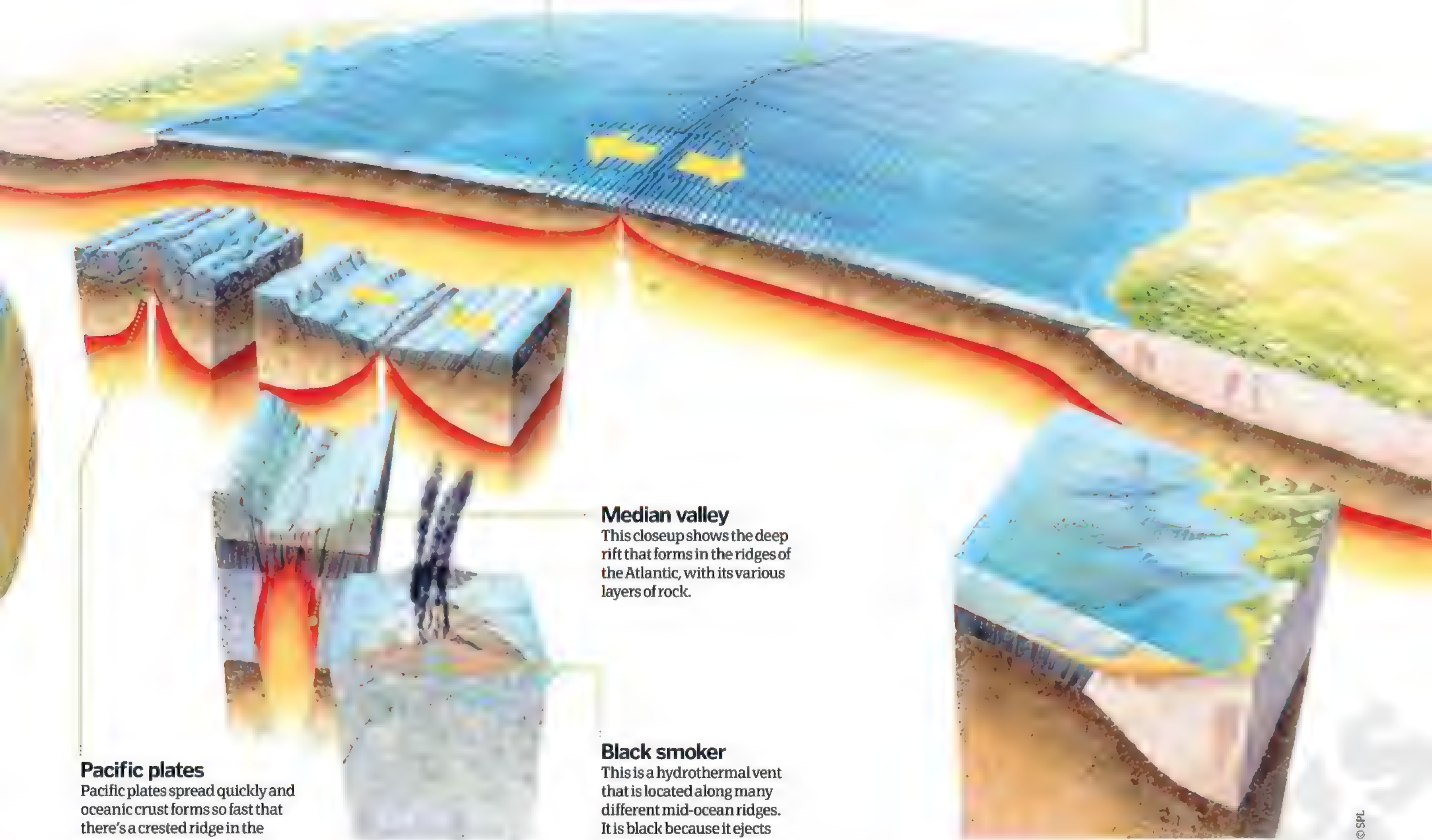
DEEPEST POINT: 7,758m (25,453ft)

YEAR DISCOVERED: 1872

DID YOU KNOW? *We think of the seafloor as stable, but it's actually spreading continually due to volcanic/seismic activity*

Seafloor evolution

The terrain of the ocean floor is changing all the time due to the ongoing activity occurring in the mantle below the Earth's crust



Atlantic plates
Atlantic plates are slow spreading, which results in a deep valley forming between the plates.

Lava
Lava cools in the ocean and builds up in a ridge.

Molten rock
Magma rises up through weaker spots in the ocean crust.

Median valley
This closeup shows the deep rift that forms in the ridges of the Atlantic, with its various layers of rock.

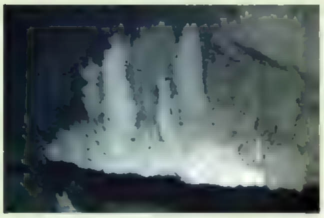
Pacific plates
Pacific plates spread quickly and oceanic crust forms so fast that there's a crested ridge in the centre, rather than a valley.

Black smoker
This is a hydrothermal vent that is located along many different mid-ocean ridges. It is black because it ejects sulphuric minerals.

2 x © SPL

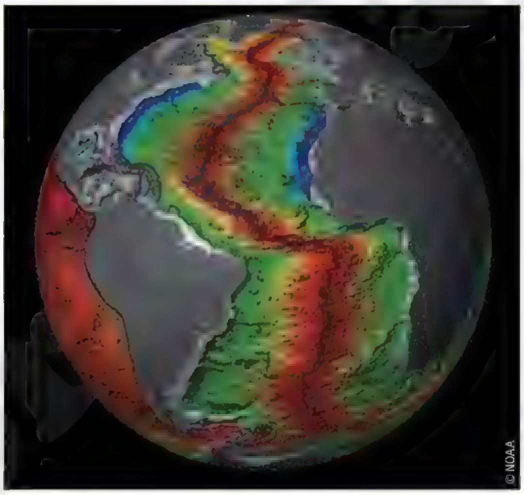
5 Hydrothermal vents

These hydrothermal vents are located in the same region as the Atlantis Massif. They're essentially openings in the crust where geothermally heated water spews into the ocean. They vent a lot of methane and hydrogen into the water, and this has created a unique ecosystem in the ocean depths.



What lies beneath…

The Mid-Atlantic Ridge actually sits on another formation in the ocean, which is called the Mid-Atlantic Rise. This elevation is a sort of bulge off the ocean floor, which is caused by immense pressure in the mantle pushing up through the crust. The Mid-Atlantic Rise is thought to have formed during the Triassic period, dating back to about 200 million years ago. The central valley of the Mid-Atlantic Ridge experiences a lot of earthquakes as well, which is probably also due to the instability in the mantle. Because of the continual seismic and volcanic activity the ocean floor here is slowly but consistently spreading along the ridge at a rate of 2.5 centimetres (one inch) per year.

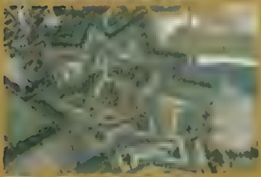


© NOAA

Welcome to... HISTORY

To many Art is [illegible] of [illegible], but how did Da Vinci's ornithopter work in principle? We also discover why star-shaped fortifications [illegible] for centuries, before looking at the [illegible] and [illegible] of one of Europe's bloodiest conflicts ever, the Battle of Agincourt.

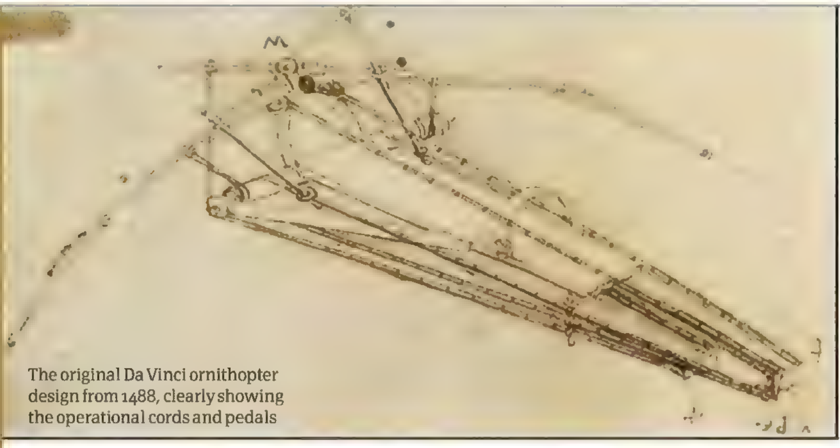
74 Mustard gas



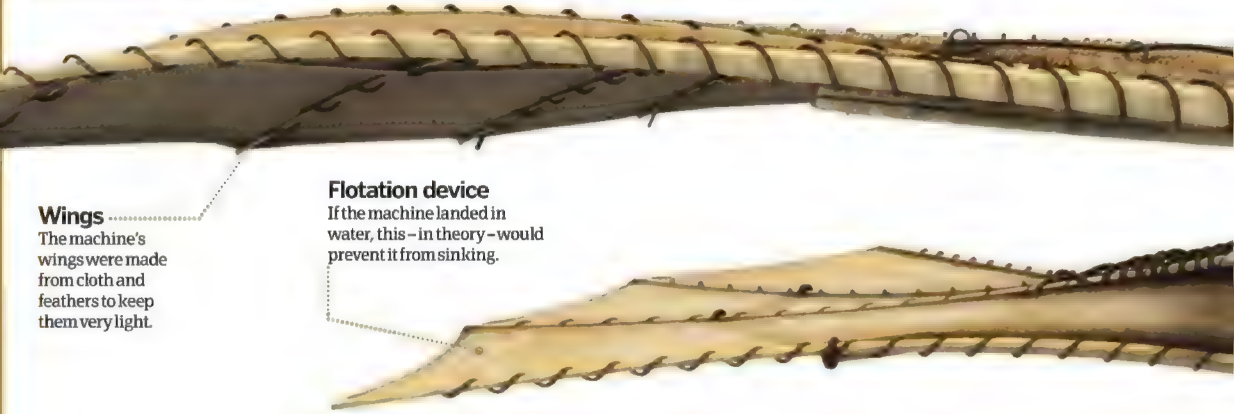
75 Star forts

76 Agincourt

LEARN MORE



The original Da Vinci ornithopter design from 1488, clearly showing the operational cords and pedals



Wings The machine's wings were made from cloth and feathers to keep them very light.

Flotation device If the machine landed in water, this – in theory – would prevent it from sinking.

Da Vinci's flying machine

Discover the operation of one of Da Vinci's most famous aviation designs, the ornithopter

☎ This image is a 3D interpretation of Leonardo Da Vinci's flying machine, the ornithopter. Da Vinci designed the contraption in 1488 after studying the flight mechanics of birds. Indeed, in many regards the flying apparatus shares a lot of common features to the expert fliers, including a flexing, compound flapping motion as well as lightweight, feathered wings.

The flying machine operates as follows. A pilot lies down on top of the central wooden plank, hooking their neck and head through the semi-circle hoop and legs through the rear fastener. Once in position, the pilot can operate all parts of the machine with either their hands or feet. Foot operation entails pushing on two pedals situated at the rear of the aircraft – one opening the wings and the other closing them. The pilot's hands, meanwhile, can grip the frame and ensure smooth running of the cording, which is responsible for controlling the wings' multiple wooden struts.

Surprisingly, Da Vinci never built the machine for himself in the 15th century, nor did he proceed to test it – maybe due to the financial challenge such a project would entail, or the large potential for injury. In addition, while many enthusiasts have created direct replicas of the ornithopter from the original schematics, no one has attempted to fly them, despite the mechanisms having been confirmed as fully functional.

5 TOP FACTS
FAILED FLIGHTS

Pigeon
1 According to Ancient Roman sources, the Greek mathematician Archytas invented a bird-shaped flying device which he nicknamed 'the pigeon'. It is alleged to have flown for 200m (656ft).

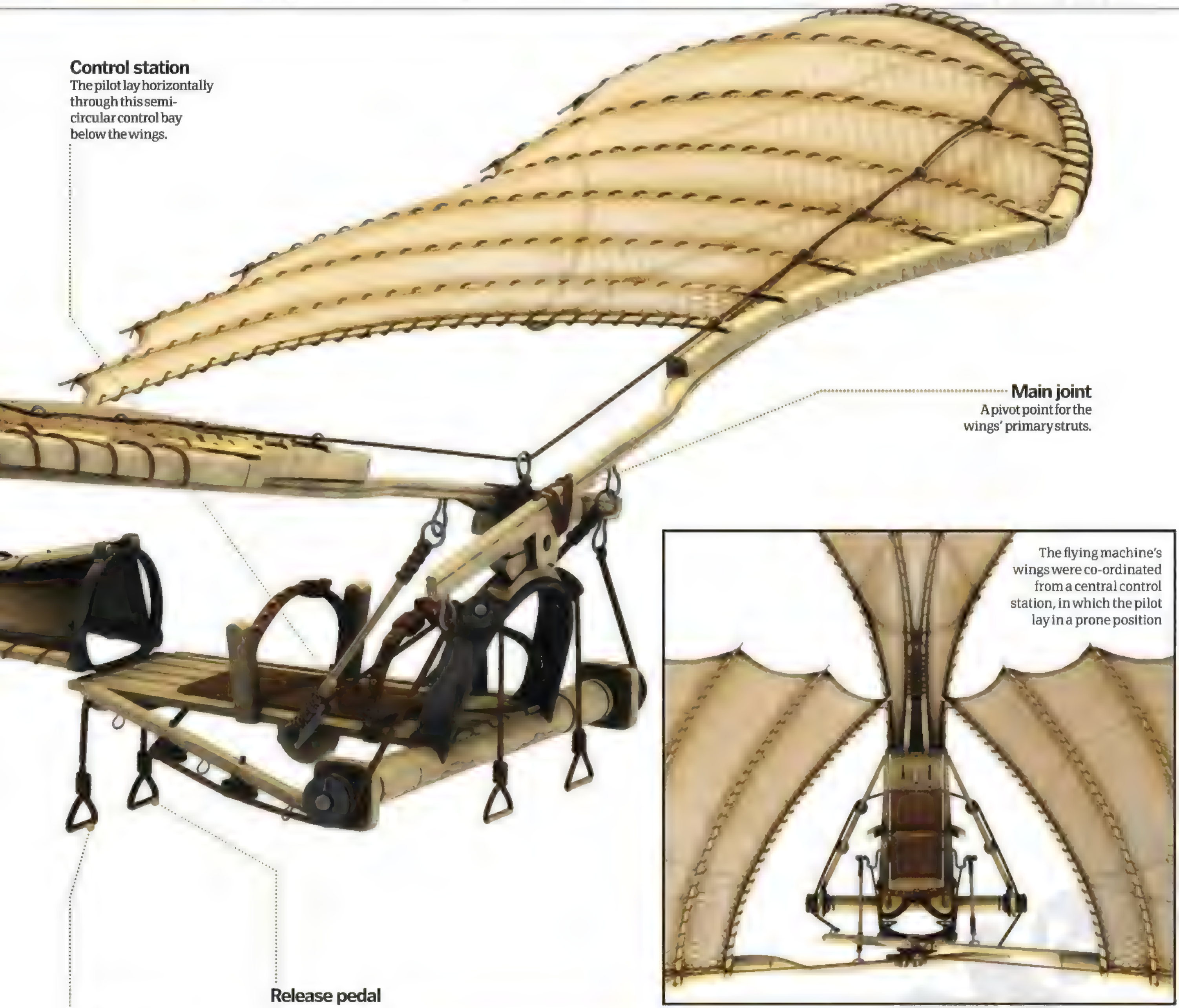
Vulture man
2 In the 9th century CE, Muslim inventor Abbas Ibn Firnas reportedly covered his body with vulture feathers and tried to fly. No account survives of his success, however.

The flying monk
3 In 1010 English monk Eilmer of Malmesbury is believed to have jumped off Malmesbury Abbey in a primitive gliding craft. Reports say he flew 180m (591ft) before crashing.

Airship
4 In 1709 Portuguese priest Bartolomeu de Gusmão demonstrated a small airship model before the Portuguese court, but he never succeeded in scaling the model up.

Tandem
5 In 1754 Mikhail Lomonosov showed a tandem rotor aircraft to the Russian Academy of Sciences. Similar to one of Da Vinci's designs, it was self-powered by a spring.

DID YOU KNOW? *In 1505, Da Vinci wrote Codex On The Flight Of Birds; this document would inspire many of his flying machines*



The flying machine's wings were co-ordinated from a central control station, in which the pilot lay in a prone position

Who was Da Vinci?

An irrepressible inventor, Da Vinci created many machines and gadgets still in use today

Leonardo Da Vinci was an Italian Renaissance polymath (a learned person of many talents). He successfully conceived and built a wide number of tools, mechanisms and machines, many of which are still used in some form to this day. Examples include the machine gun, armoured car, bicycle, mechanical saw, dredger, file-cutter, excavating crane, mechanical drum and odometer.

In addition, he drew out numerous fantastical designs for more ambitious inventions that unfortunately never got adopted, one of which was the flying machine examined here. Other examples include a mechanical dragonfly, a self-propelled cart and a skull-shaped lyre. Da Vinci was born near Vinci, Italy, in 1452 and died near Amboise, France, in 1519, aged 67.

> "Surprisingly, Da Vinci never built the machine for himself in the 15th century, nor did he test it"

"These cranes were used in construction and industry for lifting all manner of materials"

What was mustard gas?

How did this chemical weapon wreak such devastation?

Mustard gas, a nickname for a variety of sulphur mustard agents, was a class of related cytotoxic (ie toxic to cells) chemical weapons used primarily in World War I and World War II. The agents worked by preventing cellular division within the victim, leading to programmed cell death, DNA damage and, in some cases – where the victim survived the immediate effects – cancer in the long term.

In addition to the direct life-threatening capabilities of the gas, it was also a major irritant to the skin, eyes and respiratory system, leading to large yellow-fluid-filled blisters and chemical burns. Further, the gas had strong mutagenic effects on those it came into contact with, often resulting in severe disfigurement.

The gas was typically delivered onto a battlefield via artillery shells or, particularly in WWII, aerial bombs.

Today, the use, production and sale of mustard gas is strictly prohibited and, as such, it is not used in modern conflicts, with existing weapons either strategically destroyed or stockpiled within secure facilities.

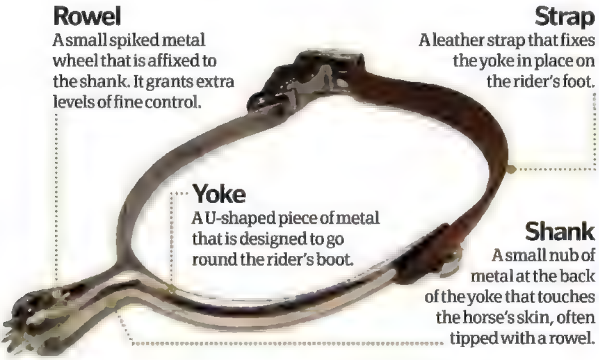
A [illegible] mustard gas [illegible]

Pallets of stockpiled artillery shells filled with distilled sulphur [illegible] warning poster from WWII

How riding spurs work

Why are these an essential part of any horse rider's kit?

Spurs are small metal tools that are attached to a rider's boots. They're used across most equestrian disciplines today and, historically, were used by the vast majority of military orders. Spurs are designed to grant horse riders the ability to transmit subtle commands to their horse via pressure and strokes of a metal shank or rowel (see image below). Riders initiate spur commands by flexing their heel upwards and inwards slightly, pressing the metal element against the horse's body. The motion and intensity of this pressure directly translates to a certain (taught) command, though the majority indicate changes in speed or direction.



Treadwheel cranes explained

Styled like colossal human hamster wheels, these cranes allowed huge loads to be hoisted with ease

[illegible]

A [illegible] from Bruges, [illegible]

© Donarreiskoffer

HEAD 2 HEAD

FORTIFICATIONS

1. OLD


© Nitot

Motte-and-bailey castles

The motte-and-bailey was a castle built on top of a natural or man-made mound. The walls and keep were usually made of stone.

2. OLDER

Citadel

A citadel was a structure attached to a large town or city, either within its outer walls or part of them. Citadels provided a base for the city's soldiers.

3. OLDEST

Hill fort

One of the earliest defensive man-made structures, hill forts were large earthworks consisting of a series of earthen walls and ditches built around a small settlement.

DID YOU KNOW? *Star forts were used by Michelangelo in the defensive fortifications of Florence, Italy, in the 16th century*

The science of star forts

Why are these spectacular fortifications shaped this way?

Star forts are a type of fortification that remained popular from the mid-15th century right up until the end of the 19th and they evolved for two main reasons. First, they aimed to counteract the game-changing effects of gunpowder during sieges, with traditional square and ring-shaped forts now easily breached by cannon fire. Second, star forts also mitigated a key defensive weakness traditional forts had become increasingly vulnerable to – 'sapping', or mining under the walls, by foes out of the firing line.

Star forts countered – to a degree – the effects of cannon fire by removing most perpendicular targets for the attacking force. The design was chosen as cannon balls made short work of square-on fortifications largely due to their extensive surface area and lack of absorptive support when a shot made contact. This was because medieval castle and fort walls, which accounted for a large proportion of existing strongholds, had been designed to be relatively thin but high, making it hard for enemies to scale them and difficult for siege engines to fire over. The advent of cannon fire, however, allowed these walls to be hit directly and with a ferocity that would easily demolish the stone and clay.

As such, this new form of fortification was built out of a series of interlocking and/or separate triangular bastions, which encircled the central town or keep within. The bastions were much thicker than standard walls and much flatter too, meaning that any cannon shot hitting them straight on would have its kinetic energy spread out and absorbed by successive layers of masonry. Further, any shot that was not a direct hit, or completely perpendicular, would glance off with little damaging effect.

The second reason why the star-shaped fort became widely adopted was that while it limited effective angles of attack for the offensive enemy force, it maximised those of the defensive one. This was due, simply, to the geometry of their bastions. By creating a series of triangular spits that could be manned by gunners, attacking forces could be engaged over a far greater angle – over 180 degrees – and, more importantly, those forces that did reach the walls, could be continuously fired on from the side and rear. These advantages were generally not granted by existing strongholds, as their flat-on walls meant infantry could only fire in a small arc in one direction – ie perpendicular to the wall. If forces did manage to reach the base, they could not be effectively engaged either as shooting straight down is very awkward.

Despite originating in the mid-15th century in Italy, by the 18th century star forts were a common sight in France, Germany, Croatia, Hungary and many other western nations (later spreading as far east as Japan). Many are acclaimed in historical record as key turning points in major battles. Indeed, the reign of the star fort only came to an end with the arrival of explosive shells towards the latter end of the 19th century.

> *"While star forts limited effective angles of attack for the offensive enemy force, they maximised those of the defensive one"*


A top-down view of Fort Bourtange, a star fort in Groningen, Netherlands

© Google


Fort Goryokaku, a rare surviving star fort in Hakodate, Japan

"The battle was one of the bloodiest meat-grinders ever witnessed"

Battle of Agincourt

The most famous conflict of the Hundred Years' War, the Battle of Agincourt was one of the most bloody and brutal in history

The Battle of Agincourt is one of Europe's most famous battles, echoing down the centuries in historical record, song and even dramatic re-enactment on stage and film. The battle itself was part of the Hundred Years' War, a series of conflicts that actually waged for over a century (1337-1453) between the Kingdoms of England and France for control of the French throne.

The two contenders for the throne were the House of Valois, a noble French family from the Capetian dynasty that had claimed the throne under Salic Law, and the House of Plantagenet's Angevin family, who contested the claim due to the ancestral marriage of Edward II of England to Isabella of France. These contested claims led to a number of brutal battles throughout the 14th and 15th centuries, which came to a head in the Battle of Agincourt, a horrific battle fought between King Henry V and King Charles VI on 25 October 1415.

The battle itself was a major English victory against a numerically superior French army – see 'Agincourt battle map' for a comprehensive rundown – that rested on a series of tactical mistakes by the French, commanded by Constable Charles d'Albret, and a series of tactical masterstrokes by King Henry V. Indeed, Agincourt has gone down in French history as one of their most disastrous defeats, with around 8,000 French troops killed and hundreds of others wounded or taken prisoner. In contrast, the English losses were in the low hundreds.

Interestingly, however, despite the conflict being such an obvious and celebrated English victory, the battle is remembered today more for its vivid representation of the polarised views and consequences that war in general generates (for William Shakespeare's take on this, see 'The turning of the tide' boxout over the page). There are a number of reasons why opinions about it are so divided.

The first is due to the sheer magnitude of the casualties and the way in which they died. Records indicate men were decapitated, cleaved in two, had their bones shattered, were trampled to death, suffocated and had their major organs shredded by arrows. The battle was, without doubt, one of the bloodiest meat-grinders ever witnessed.

The second, and arguably more poignant reason, is despite Henry winning the day at Agincourt and later being named regent and heir to the French throne – a goal he had chased all his adult life – he died before he could be crowned and his successors proceeded to quickly lose both the throne and much of the territory in mainland France that he had won through his campaign.

Lastly, despite Henry's actions being accepted as justified at the time by both French and English chroniclers, his actions were heavily criticised both morally and ethically in later times. Arguments not only

5 TOP FACTS BATTLE OF AGINCOURT

Victory songs

1 After the English victory at Agincourt, several celebratory songs were written. The most famous of these is *The Agincourt Carol*.

V

2 The derogatory 'V' sign of modern culture stems from Agincourt. The gesture was used by English archers in defiance of the French threat that any caught longbowmen would have their two bow-fingers cut off.

Outnumbered

3 One of the most contended issues today is exactly how badly the French outnumbered the English forces. Conservative figures lie around 4:3, while other estimates place it at 4:1 or even 6:1.

Welsh allies

4 The English forces at Agincourt were not just from England but Wales too. Indeed, one of the most notable generals, Dafydd Gam, died in the battle after reportedly saving Henry's life.

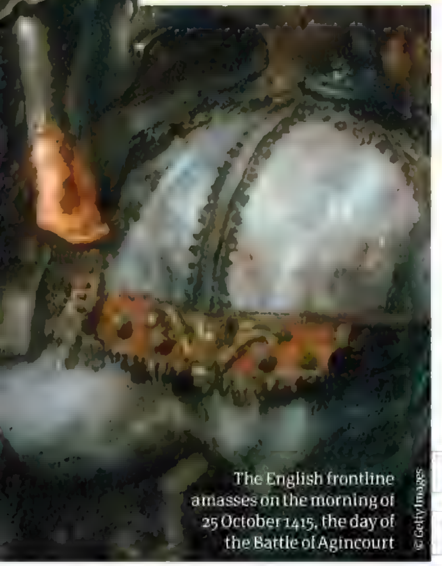
The waiting game

5 Despite Henry's resounding victory, he was not officially recognised as regent and heir to the French throne until 1420, five years after the conflict.

DID YOU KNOW? Actor Kenneth Branagh played Henry V in the 1989 film adaptation of Shakespeare's play

Agincourt today. Despite almost 600 years having passed since the famous battle, the terrain is still ploughed fields, a factor that g[illegible] contributed to the English v[illegible]

© Alamy



The English frontline amasses on the morning of 25 October 1415, the day of the Battle of Agincourt

© Getty Images

contested his right to invade, but also his decision to execute all but a handful of the French prisoners taken at the battle, which while numbers are unclear, probably approached, or even exceeded, a thousand men. Indeed, the French losses at Agincourt largely obliterated their aristocracy, with hundreds of noblemen (including three dukes, eight counts and one viscount), knights and even an archbishop killed in the fighting.

In this feature How It Works breaks down the main events of the battle itself, analyses the surrounding context, highlights the key players and explores the ramifications that Agincourt had on the economic, social and political spheres of Europe in the Late Middle Ages and beyond.

A clash of kings

How It Works pits the warring monarchs of France and England head-to-head

King Charles VI		King Henry V
46	Age (at Agincourt)	29
1368	Born	1386
House of Valois	Lineage	House of Lancaster
[illegible]	Children	1
Catholic	Religion	Catholic
1380-1422	Reign	1413-1422
Charles V	Predecessor	Henry IV
1422 in Paris	Death	1422 in Bois de Vincennes

Background: [illegible]

Background: The last of the great warrior kings of the Middle Ages, King Henry V ruled England for nine years and [illegible]

"Henry receives a blow to the head that removes part of his crown"

AGINCOURT BATTLE MAP

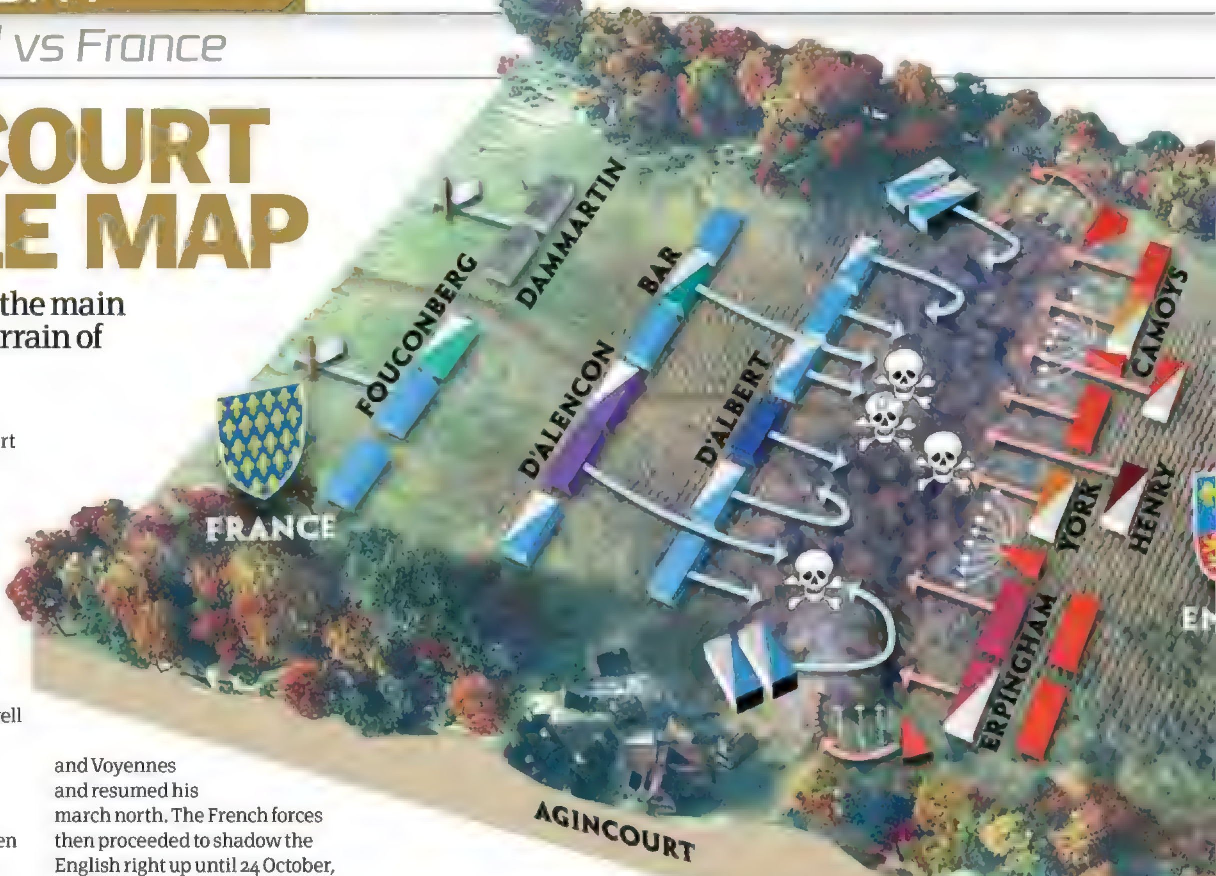
How It Works charts the main events, tactics and terrain of this famous conflict

Contextually, the two sides approached the Battle of Agincourt from completely different directions – both literally and metaphorically. Henry had been campaigning in France since 13 August 1415, which had seen him besiege and take the port city of Harfleur and cover hundreds of miles through Normandy. As a result, the English forces were tired from fighting and marching, as well as suffering from food shortages, and disease was rife.

In contrast, the French had assembled a large army during Henry's taking of Harfleur at Rouen and then moved to block Henry's crossing of the River Somme on his march north to the English stronghold of Calais. The French forces were much fresher, substantial in number – with many nobles and soldiers alike amassed – and better equipped. All these factors led them to believe, quite understandably, that if a battle did happen, they would win decisively.

After being initially prevented from crossing the River Somme, Henry finally managed to cross it south of Péronne at Béthencourt and Voyennes and resumed his march north. The French forces then proceeded to shadow the English right up until 24 October, where they met them at Agincourt. The French, however, did not engage the English immediately, as they were expecting additional troops to arrive to support them. As such, the first day passed without incident, setting up 25 October as one of the most famous days in European military history.

For a blow-by-blow account of the battle, read through our chronological guide of the main events, which can be followed directly on the battle map.



Unit guide

French

Standard: Arms of the Kingdom of France
Men (estimate): 12,000-36,000
Archers and infantry: Blue ■
Cavalry: Blue and white ■□
Constable Charles d'Albret: Dark blue ■
Duke of Alençon: Purple ■
Duke of Bar: Turquoise ■
Count Fauconberg: Cyan ■
Count Dammartin: Silver ■

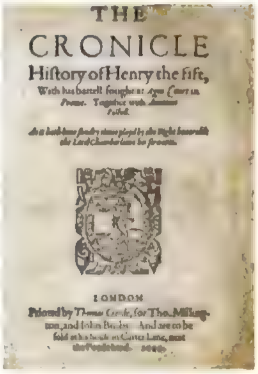
English

Standard: Royal Arms of England
Men (estimate): 6,000-9,000
Archers: Red triangle ▲
Infantry: Pink ■
Cavalry: Red and white ■□
King Henry V: Maroon ■
Duke of York: Orange ■
Sir Thomas Erpingham: Green ■
Baron Thomas de Camoys: Yellow ■

The turning of the tide

Shakespeare's dramatic re-enactment of the Battle of Agincourt in Henry V sends out some mixed messages

William Shakespeare's play *Henry V* (c. 1599) is interesting in its ambiguously polarised views on the battle, Henry himself, and war in general. On one hand, Shakespeare appears to praise military conquest and justify Henry's campaign – most notably in his famous St Crispin's Day speech, where Henry rallies his men. On the other hand, the play doesn't shy away from detailing the horrors of war and even closes with a reminder that, while Henry's victory won him the French throne, in the long term his son lost it and the battle was, historically, largely inconsequential.


THE
CRONICLE
Hiſtory of Henry the fift,

LONDON

Step-by-step event guide

How did Henry V lead the English to victory?

1 Henry advances towards the French frontline, ordering his archers to uproot their defensive spear wall and replace it farther up the battlefield. This catches the French forces off-guard and they fail to charge before the spear wall is reinstated. English longbowmen in the central frontline begin bombarding the French with arrows.

2 While the French frontline try to quickly organise themselves for a frontal charge, Henry orders his flanking squads of longbowmen to move up the battlefield within the trees to the right and left, advancing to a point where they can fire from either flank into the centre of the French troops. Like the frontline archers, they set up spear walls.

3 Constable D'Albret orders the French frontline to charge at the English frontline. They are met by multiple waves of arrows, which decimate large

STRANGE BUT TRUE
PLAY FIGHTING

BLOODLESS BATTLE

Despite Shakespeare's play *Henry V* revolving entirely around the Battle of Agincourt, the stage production actually features no depiction of combat whatsoever, focusing instead on events before and after the fighting.

DID YOU KNOW? As well as being famed for his military prowess, Henry V was also considered a shrewd political diplomat

Where it went wrong for the French

Drawing on the lessons of military history, we weigh up where Charles d'Albret's strategy foundered, and how the French might have won the battle

Key to Henry's victory was his good use of tactical positioning and Constable D'Albret's poor use of it. Indeed, with D'Albret's bigger and fresher force, he arguably should have won the battle if he had made a few key adjustments.

First, if D'Albret had engaged Henry's forces on a more open terrain, he would have been able to better utilise his large selection of cavalry, which during the skirmish could not outflank the English forces and so were forced to charge head-on.

Second, D'Albret totally underestimated the damage that could be inflicted by the English longbowmen, who were the best archers in the world at the time. As such, French cavalry and infantry alike were continuously bombarded from the front and sides by Henry's well-placed units, severely decimating their troops before they even reached the English frontline. Once again, a more open terrain could have avoided this.

Third, and last, D'Albret's forces – notably the French army's noble knights – were outfitted in heavy armour. While such gear provided a greater degree of protection in hand-to-hand combat, it severely limited their movement and agility, something that would become fatal on the busy, muddy central battlefield. Indeed, reports indicate that the battlefield became so cramped and sodden that when knights were knocked down they struggled to even stand back up again, let alone efficiently engage the lighter-armoured, and so more agile, English troops.

numbers of their cavalry and infantry as they cover the central battlefield. The English archers on each flank also begin firing, hitting the French frontline from both sides.

4 D'Albret and limited numbers of the French frontline reach the English spear wall and begin to engage them in hand-to-hand combat, pushing it backwards. The longbowmen retreat and Henry orders his infantry to advance and meet the French.

5 Fierce, close-quarters fighting begins upon the sodden, muddy ploughed terrain at the centre of the battlefield. The combination of the dense mud and heavy armour worn by the French knights leads to thousands of them getting severely bogged down and exhausted, with the lighter-armoured English forces able to operate much more effectively.

6 D'Albret is suddenly killed in the melee, falling into the mud. Meanwhile, the French second line advances into the centre of the battlefield congesting it further. At this point the two side flanks of English archers abandon their ranged weapons and rush into the French second line from both the right and left.

7 The Duke of York is killed by a blow to the body and proceeds to get lost amid the sea of fighting soldiers. In addition, Henry's brother – Humphrey, the Duke of Gloucester – is wounded by a blow to the groin. Henry quickly moves to his position and defends him with his personal retinue – he succeeds but in the process receives a blow to the head that removes part of his crown.

8 The Duke of Bar is killed as his forces get depleted by the encircling English. Upon seeing the disaster that is unfolding before his eyes, the Duke of Alençon attempts to reach the English to submit a surrender notice, however he is killed by a blow to the head before it can be delivered.

9 The third line of French forces hovers on the outskirts of the battle, unsure whether to fight or not. Henry perceives they will and, due to the large number of unrestrained French prisoners from the first and second waves, orders all but the most high-ranking to be executed to prevent them from rearming en masse and overrunning the exhausted English.

10 Upon seeing the vast losses and executions, the French third line, led by the Counts Fauconberg and Dammartin, retreat to the rear, fleeing the battlefield. Henry wins the battle and orders a count of the dead, which reveals roughly 8,000 French troops had died compared to the English's 450.

The mad king

King Charles VI wasn't at Agincourt as his court considered him unstable, but was he?

Charles VI's reign was blighted by an apparent mental illness, which manifested itself in a series of conditions ranging from him believing he was made of glass to outright paranoia and violent episodes. One of the most notable of these episodes was during a march to Brittany from Paris to punish what Charles VI perceived to be a would-be assassin. After being warned by a passing leper that he should turn back as he was betrayed, he reportedly suddenly shouted, "Forward against the traitors! They wish to deliver me to the enemy!" and proceeded to hack down and kill several of his personal bodyguards (see picture below). After finally being dragged from his horse, Charles fell into a coma. As such, and especially towards the end of his reign, he was largely confined to his residence in Paris and – as a direct consequence – did not lead his forces at the Battle of Agincourt.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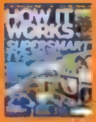


Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He's been writing about science and tech for years. His sci-fi novel *A Jar Of Wasps* is published by Anarchy Books.

Shanna Freeman

Science expert Shanna Freeman has a refreshingly broad range of expertise, which includes writing on such varied topics as space travel, nuclear power generation and how cheese is made.

Rik Sargent

Rik is an outreach officer at the Institute of Physics where he works on a variety of projects aimed at bringing physics into the public realm. His favourite part of the job is travelling to outdoor events and demonstrating 'physics busking'.

Mike Anderiesz

Long-time *How It Works* contributor and seasoned technology and computing journalist Mike has 15 years' experience of explaining the ins and outs of all the latest gadgets, hardware and home entertainment products.

Aneel Bhangu

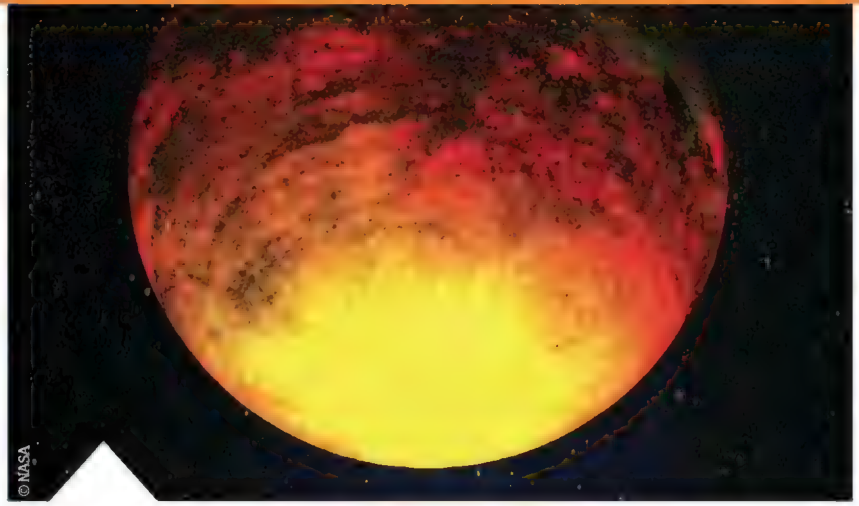
Aneel is a training academic surgeon working in London. His research interests include advanced cancers and medical statistics, with his clinical interests including planned surgery for rectal cancers and emergency surgery for trauma.

Is there a limit to quantum computing?

Jamie McDonald

Today's computers process data as bits, which can exist either as a 0 or a 1. Hard-disk drives store these bits as microscopic patches of magnetism on magnetic plates, where the information can then be converted to electrical signals. Quantum computing, meanwhile, manipulates data at an atomic level, allowing for a whole host of interesting quantum mechanical effects. Bits in quantum computing are known as qubits and are particles such as electrons or atoms. The advantages of qubits are that they are very small and can exist in more states than just two. These states could take the form of the spin of an electron or the configuration of an atom, and because there is a higher number of states per qubit than an ordinary bit, the number of possible combinations of states between different qubits increases massively. This essentially means that quantum computers would be able to solve immense calculations at unfathomable speeds, compared with traditional machines. However these particles are very difficult to manipulate so quantum computing is currently limited in what it can do, but as for the future, it's impossible to predict how far this technology could go.

Rik Sargent



© NASA

If the Earth was once molten, where did all the water come from?

James Blanchard

The Earth is the only planet in our Solar System with huge amounts of water that has mostly remained in the same liquid state ever since it first formed. The latest theory explains that, after the world formed – but before it had developed an atmosphere – a variety of gases were released from the interior. This 'degassing' process lasted for about 100 million years, after which time enough gases (including carbon dioxide, methane and ammonia) existed to form the atmosphere, as well as the vast oceans which cover so much of our planet today (70 per cent). Gravity held the gases to the surface, and the temperature lowered below the boiling point so the gases could condense into water. Other possible contributors include water-rich meteorites and comets colliding with the Earth's atmosphere, and the photosynthetic processes of bacteria that existed early in the planet's life.

Shanna Freeman

If you've something to shout, don't forget to take a deep breath first

How do we control the volume of our voices?

Stacey John

The human voice is produced by air from the lungs moving over the vocal cords in the larynx. The cartilaginous larynx is situated in the throat, below the tongue and above the lungs. The vocal cords themselves are formed from a combination of muscle and cartilage. As they contract and relax, the space between them increases or decreases, which in turn changes the tone and pitch of the voice. However it is the force and speed of air passing over them which dictates the volume of our voices, and this air originates from the lungs. So when you want to speak loudly, you take a deep breath in to fill your lungs before expelling the air rapidly and forcefully over the vocal cords.

Aneel Bhangu

What is déjà vu? Find out on page 85

The 2m (6.6ft)-tall genyornis is believed to have been driven extinct by human hunting and habitat destruction

© Nobu Tamura

Which was the first species made extinct by humans?

Billy Rowlatt

We don't know for certain but it was probably one of the giant mammal species of the late-Pleistocene epoch (60,000-12,000 years ago). Recent studies of the two-ton wombat diprotodon and the two-metre (6.6-foot)-tall flightless bird genyornis, for example, indicate that they became extinct from Australia soon after humans arrived. These animals would either have been hunted directly or driven extinct by environmental destruction as early humans lit brush fires to flush out other prey and clear land for settlement.

Luis Villazon

When will videogames look like real life?

Jonathan James

In some respects, the CG animations used in videogame cut-scenes can already look uncannily realistic. However, the human eye works differently to a monitor, and the brain very differently to a computer, so the way we perceive realism and the way we re-create it are hard to compare. For starters, our eyes and retinas are curved. So although we can easily calculate, say, the screen resolution of a videogame in dots per inch (dpi), that assumes viewing it on a flat screen of a fixed size at a fixed distance. However, human vision works in arcs – an object's sharpness and clarity appearing minutely different depending on how close it is. Today's videogames and monitors can comfortably handle resolutions of up to 1,920 x 1,080 dpi, but the human eye is capable of seeing much more subtle detail. Videogames are also viewed on a single screen whereas we see the world with two eyes that cover much wider peripheral vision. Even when playing a 3D game on several linked 3D monitors, it's a long way from being as convincing as the real thing.

Mike Anderiesz

L.A. Noire featured the most realistic facial animation ever seen in a videogame

© Rockstar Games

BRAIN DUMP

Because enquiring minds want to know...

Can gold ever be vaporised?
Find out on page 86

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

Can you do a loop-the-loop in a passenger jet?

Dave Porter

■ To perform a 360-degree loop, an aircraft needs to achieve three phases in quick succession: the entry, the climb and the exit. Each of these would cause particular problems to anything the size and weight of even a small commercial jet. Entry has to be undertaken at top speed to carry the plane through vertical ascent, making optimum fuel load a tricky calculation.

At this velocity, the climb would put massive strain on the wings and tail – enough to tear them from the fuselage. Finally, the jet's weight would be too great and flight controls too weak to pull out of the loop without causing vibrations that could rip the aircraft apart. Needless to say, nobody has found a pilot brave enough (or airline dumb enough) to try it!

Mike Anderiesz

A fossilised skeleton of megalania in Melbourne Museum

What's the biggest lizard ever to live?

Robert Ansil

■ If you were tempted to think 'some kind of dinosaur', then think again – dinosaurs were similar to reptiles but weren't lizards. The answer is varanus priscus, or megalania, a terrestrial lizard native to Australia that became extinct over 40,000 years ago. Although most experts agree megalania was the biggest ever, opinion is divided on just how big it was, with estimates varying between 4.5-7 metres (14.7-23 feet). This is because no complete skeletons have been found, although fossil fragments do suggest megalania was heavily built with a mouthful of sharp, serrated teeth. The world's largest living lizard is a distant relative of megalania, the Komodo dragon, which is a kind of monitor lizard.

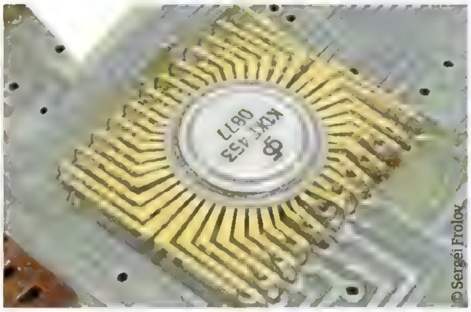
Mike Anderiesz

Why are microchips made of silicon?

Diana Easton

■ Most microchips are currently made from silicon due to its effective semi-conducting properties. A semiconductor is something which conducts electricity, but only partially. Semiconductors are the foundation of most electronic devices as they allow the building of gates and switches in a circuit. Pure silicon is actually an insulator, and becomes a semiconductor through a process known as doping. Doping involves introducing small amounts of impurities, giving rise to free electrons or 'holes' that electrons want to move into. Silicon has been so widely used in microchips as it is easy to extract from sand in large quantities, and gets the job done. However current research suggests that materials such as carbon graphene are able to outperform silicon, and could represent the future of consumer electronics.

Rik Sargent



© Sergei Frolov

Why is reheating rice bad for you?

Sarah Phillips

■ It's all in how you cooked and handled the rice. Rice naturally contains the spores of a bacterium called bacillus cereus. If you cook rice correctly, then store in a calibrated refrigerator within two hours, you have nothing to fear. The problem comes when cooked rice is kept at an unsafe temperature for a long period of time as this allows the spores to breed. No amount of reheating after that can kill them, and eating the rice can cause diarrhoea and vomiting. Any food cooked and stored improperly can make you sick, but many people don't know rice is a potential culprit.

Shanna Freeman

How do you fix a dislocated limb?

Jake Westcott

Joints are vital to allow movement and function to an otherwise rigid skeletal frame. The more free the movement, the less stable the joint. For example, both the hip and shoulder are ball-and-socket joints. Since the hip has a deeper socket, it is more stable but this comes at the cost of restricted movement. The shoulder has a shallower joint and allows more freedom of movement, but is less stable.

When a joint dislocates (such as after a fall or a sports injury), contact between the surfaces of the bones forming that joint is lost. Shoulders, fingers, toes and elbows are commonly dislocated, with knees, ankles and vertebrae less frequently. The bones must be put back in place; after some sedation, they are manipulated until they move back into the right position. Sometimes, an operation is needed, but in some cases, nothing is needed at all (such as for dislocations of the clavicle, or collarbone).

Aneel Bhangu

The ball-and-socket shoulder joint, cushioned by cartilage

What is déjà vu?

Carmen Jones

If you've seen the blockbuster film *The Matrix* then you'll know that déjà vu is a glitch. In all seriousness though, déjà vu is a phenomenon in which you feel as if you're seeing or experiencing something that has already happened. It's French for 'already seen', and as many as 70 per cent of people have had déjà vu experiences. But what causes it? There are several different theories. Some neurologists suggest the brain mistakenly processes a short-term memory (the memory you're in the process of making) as a long-term memory, making something that's new seem familiar. Another possibility is if you've learned or seen something similar, and although you've forgotten it, some aspect was stored in your consciousness, so when you have the new experience, your brain tries to match up the two. People suffering from temporal lobe epilepsy may experience déjà vu due to short-circuiting, while a number of drugs can also evoke the feeling.

Shanna Freeman

What caused the train wreck at Montparnasse in 1895?

Ryan Davies

This incredible photo of the wreck at Gare Montparnasse in Paris shows a very dramatic scene of a train that has crashed through the wall and partially tumbled to the street. The cause? Both mechanical failure and human error. The train was late, so the driver had it pull into the station at a high speed. It had two different types of braking systems: handbrakes and an air brake known as a Westinghouse brake. The conductor realised that the train was going too fast and applied the Westinghouse brake, however it didn't work. He then waited too long to use the handbrakes, which weren't sufficient due to the weight and speed of the train. The locomotive crashed through a wall and the first few cars fell towards the street below. Amazingly, only a few passengers and train employees were injured, though one pedestrian on the road below was killed.

Shanna Freeman

What's the closest we've got to the Earth's core? Find out on page 87

BRAIN DUMP

Because enquiring minds want to know...

Is diamond the hardest material?

Find out on page 87

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

What does it mean when we are 'winded'?

Caroline Ferguson

■ A sharp blow to the abdomen can cause a spasm of the diaphragm. The diaphragm is a dome-shaped muscle that separates the abdominal cavity from the thorax. It is the key muscle in the respiration system. When it flattens, the pressure in the lungs reduces and air flows in. When in spasm (like a cramp, triggered by a sudden knock), it makes it hard to breathe for a few moments; this is the sensation of feeling winded. This will relieve itself rapidly if the person keeps calm and lets the spasm run its course.
Aneel Bhangu

What caused the Tunguska impact back in 1908?

Andy Hartshorn

■ The Tunguska explosion was caused by an object several tens of metres across that detonated in an airburst five to ten kilometres (3.1-6.2 miles) above Tunguska, Siberia, in 1908. Scientific opinion is divided as to whether the object was a meteoroid or a comet fragment. The former would have been a rocky mixture of iron ore and silicon oxides; the latter would have been mainly ice. The explosion was 1,000 times more powerful than the Hiroshima bomb so virtually all of the object was vaporised in the atmosphere.
Luis Villazon

Trees flattened by the Tunguska explosion in Siberia

Gold melts at 1,064°C (1,948°F), so it still has a fair way to go until it becomes airborne...

Can gold become a gas?

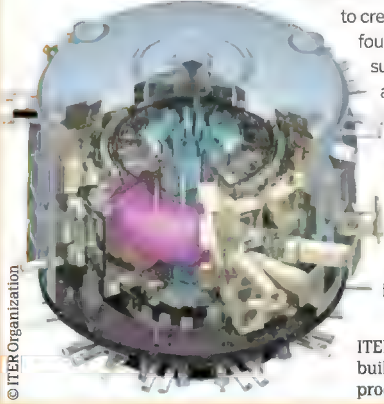
Colin Alderman

■ Any element can become a gas; you just need to heat it past its boiling point. For gold, that's 2,856 degrees Celsius (5,173 degrees Fahrenheit), which is hotter than the temperature in an arc furnace so it's difficult to just boil a bar of gold. But you can create small amounts of gold gas by bombarding it with a high-energy beam of electrons in a vacuum. This knocks atoms of gold free from the solid mass and they'll fly around and coat anything in the vacuum chamber. Electron beam vapour deposition is used to create very thin gold coatings for the electronics, medical and space industries. Gold coatings can also be used as a lubricant in machinery.
Luis Villazon

Can fusion reactors break down anything into atoms?

Nick Saunders

■ Nuclear fusion powers the Sun and it happens when hydrogen nuclei fuse together to make helium nuclei. Extremely high pressures and temperatures (around the 10-million-degree-Celsius/18-million-degree-Fahrenheit mark) inside the Sun allow fusion to occur. On Earth the temperature inside a fusion reactor has to be much higher – around 100 million degrees Celsius (180 million degrees Fahrenheit) – to compensate for our inability to create similar pressures to those found in our Solar System's star. In such extreme conditions, hydrogen and helium exist as plasma – where all the electrons are stripped of atoms and can move freely. Anything else present inside a fusion reactor would therefore break down into its elemental parts as a result of this subatomic deconstruction.
Rik Sargent



© ITER Organization

ITER is a global initiative aiming to build a 'tokamak' fusion reactor to produce a long-term energy source

Where does the fat go when we lose weight?

Puja Kumaravelu

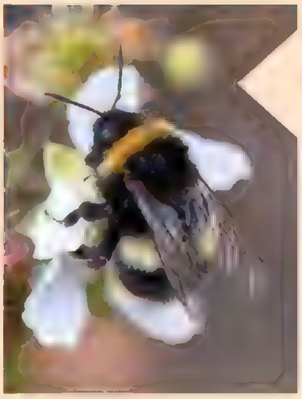
■ Fat is essential to our bodies. It stores energy, insulates us and protects us from impacts. The majority of fat is stored as subcutaneous adipose, which is the layer beneath your skin. Some is also stored in your liver and muscles. Men and women have different fat distributions with women storing most around the breasts and hips, and men around the abdomen.

Fatty acids are the basic building blocks of lipids – the small fat molecules that are transported through the blood and have many functions. Most people have a predetermined number of fat cells, which doesn't change much. As fatty acids are absorbed into the body, they are transported in the bloodstream as chylomicrons. The liver is the master controller of synthesis, storage and breakdown of fatty acids.

When glucose levels are low and more energy is needed, the stored fatty acids in fat cells are broken down into glycerol and fatty acids, which are free to circulate and then be absorbed by cells in need; this process is called lipolysis. The fat cells then shrink. So these adipose cells don't really 'go' anywhere – they merely expand or shrink depending on the nutritional status and energy demands of the body at a given moment.

Aneel Bhangu

Why do bees die after they sting us?



Jessie Joyce

■ Most bees and wasps don't. The standard stinger design is smooth for puncturing the skin of other insects and it can be easily withdrawn and reused. But the honeybee, uniquely, has evolved a strongly barbed stinger as a defence against vertebrates. The bee doesn't just push the stinger into you – the barbs on either side of the central stylus act as ratchets that move back and forth to pull the stylus ever deeper. The elastic layers of your skin trap the barbs so when you brush the bee off, the stinger tears free, along with the venom gland and part of the digestive tract. The bee dies from this huge rupture, but the muscles in the stinger continue to work, pumping venom into the wound. The abdominal juices also act as a pheromone signal to other bees to join the attack. This suicide strategy results in a much more painful sting and is the best way to protect the hive. Unlike workers, queen honeybees have smooth stingers for multiple attacks.

Luis Villazon

Is there anything harder than diamond?

Sam Smith

■ In physics, hardness is a measure of how resistant solid matter is to various kinds of permanent shape change, when a force is applied. Hardness can be measured on the Mohs scale where diamond is ranked as the hardest natural material. Diamond is made from carbon atoms joined by extremely strong covalent bonds. There are harder synthesised materials though; for instance, aggregated diamond nanorods, or ADNRs, are made by subjecting carbon-60 molecules to immense pressures.

Rik Sargent

What's the deepest hole we've ever dug?

Neil Swift

■ The record for subsurface drilling is held by the Kola Superdeep Borehole in NW Russia. The scientific project reached 12,262 metres (40,230 feet) in 1989 before 180-degree-Celsius (356-degree-Fahrenheit) temperatures forced it to stop. The trouble with drilling to Earth's core is not just the tough rock, crystal and eventually molten metal you'll encounter, but the rapidly increasing pressure, friction and heat. At around 1.5 million metres (4.9 million feet), temperatures would exceed 300 degrees Celsius (572 degrees Fahrenheit) – more than any drill-bit can cope with. Even then, we would still be over 4,500 kilometres (2,800 miles) from the inner core.

Mike Anderiesz

THE KNOWLEDGE

GAMES / BOOKS / GADGETS / TOYS

FOR CONNOISSEURS OF KIT AND SAVANTS OF STUFF

Vivid Colour Mood Light

Price: £24.95/$N/A

Get it from: www.gadgets.co.uk

Mood lighting is hugely underestimated: particularly for countries that are subjected to gloomy conditions for so many months of the year, we seem remarkably content with a standard living room light bulb. While the Vivid Colour Mood Light won't illuminate a room by itself, it will give a subtle ambience, especially to white walls. Hit the arrow and slide your finger along the colour strip to move through the spectrum of tones. It's lightweight and portable, charges from USB in an hour or so, and will provide up to two and a half hours of light per charge.

HOW IT WORKS

A LIGHTER MOOD

It's long been recognised that light has a significant effect on mood: sunlight in particular helps increase serotonin production, which elevates both your mood and energy levels.

HOW IT WORKS

MARINE MARVEL

Some coral reefs began growing more than 50 million years ago and they are some of the richest habitats on Earth.

Look Closer Ocean

Price: £6.99/$10.99

Get it from: www.dk.com

Coral reefs, the frozen poles, from the sunny surface [illegible] depths of the oceanic trenches, *Look Closer Ocean* takes young readers on an intrepid journey through the world's sealife. It's [illegible] by [illegible] and annotations, though a little lacking in text for older primary school children. However it's an interesting read and probably a good source of reference material for a first school project.

Everything You Need To Know About The Universe

Price: £14.99/$19.95

Get it from: www.anovabooks.com

When Stephen Hawking wrote his seminal *A Brief History Of Time* he was told that for every equation he included, he would halve the number of sales. Maybe author Christopher Cooper has taken that advice into account for his space tome, because this book about the universe, 'from the Big Bang to the Big Crunch, in a nutshell', dedicates two pages per topic, compiling succinct explanations with simple watercolour illustrations before moving on to the next subject. It might not help you with your astrophysics degree, but nevertheless it's a very palatable bathroom read for space fans.

HOW IT WORKS

SOLAR STATS

The Sun accounts for 99.9 per cent of the total mass of our Solar System; 90 per cent of what's left is made up by Jupiter and Saturn.

GoBook Folding Smart Case

Price: £9.99/$12.99

Get it from: www.ergoelectronics.com

You've just bought a GoBook so you're going to want a case for it, at the very least to make it more attractive to a child. Beyond aesthetics though, the GoBook Folding Smart Case will protect the screen from knocks that could potentially damage it. Not that the GoBook screen isn't designed to endure a degree of bumps and sticky fingers, but you know what kids are like.

HOW IT WORKS

FIRST TABLET

The invention of tablet computing is often attributed to Apple, but Roger Fidler has video proof of a sales pitch for his tablet newspaper device, which he conceived back in 1994.

HOW IT WORKS

UP IN ARMS

The chipset behind the GoBook is the Boxchip E200, a form of ARM processor. The first ARM processors date back to 1983 and they have been used in 90 per cent of portable devices since.

GoBook Imagine

Price: £74.99/$129.99

Get it from: www.ergoelectronics.com

With Kindle dominating the eReader market and Apple pretty much sucking up what's left, it's got to be hard to find a niche, but the GoBook might have one: it's an eReader designed for children. At a hardware level it's fleshed out with a 20.3-centimetre (eight-inch), 800 x 600px touchscreen, 4GB of internal [illegible] slot, an internal speaker with a 3.5-millimetre [illegible] transfer or charging. Its bespoke OS supports 720p AVi and MP4 files, standard music file [illegible]

The model we reviewed has no Wi-Fi access, which, on the plus side, allows you to maintain a greater level of control over what your child is reading. The grey chassis isn't likely to excite most kids and it takes a bit of wrestling with the operating system to set the GoBook up. But as a bigger, more child-friendly alternative to the standard Kindle, it's an attractive competitor.

Easy Pull Corkscrew Set

Price: £12.95/$N/A

Get it from: www.gadgets.co.uk

Given the choice between a railgun, a bearproof armoured suit and the Easy Pull Corkscrew Set, we went for the latter. And we stand by our decision, because even if it's nowhere near as [illegible] a bottle of wine open quicker than this. Few things will do the job with as much style either.

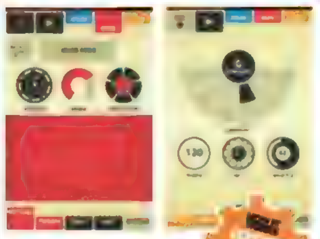
HOW IT WORKS

LEVERAGE

Rather than using a twisting motion from the weaker muscles in your wrist, the Easy Pull mechanism leverages the relative power of your upper arm.

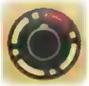
APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps [illegible]



iPad: Figure

Price: £0.69/$0.99
Developer: Propellerhead Software AB
Version: 1.0 **Size:** 9.5MB **Rated:** 4+



The first time you use Figure there is no doubt you will be stunned by the polished audio you can produce, and that's all down to the clever balance between complete freedom to create what you want, and a constant stabilising factor that keeps the audio listenable. It feels like it has taken inspiration from a spaceship dashboard, yet retains a hipster element that you associate with some of the trendier photo-sharing apps. It may not have the depth that professionals would be looking for, but Figure is a huge leap forward for synth apps.

Verdict: ★★★★★

iPhone: Zombies, Run!

Price: £5.49/$7.99
Developer: Six to Start
Version: 1.3 **Size:** 270MB
Rated: 12+

One of the most ingenious apps we've encountered for some time, Zombies, Run! gives any cardio workout an edge by putting you in the middle of a zombie apocalypse. The session kicks off when the undead start to chase you. Functioning in the same way as interval training you'll have to leg it away from danger as fast as you can or risk having your brain eaten!

Verdict: ★★★★★

Apps

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GROUP TEST

PUTTING PRODUCTS THROUGH THEIR PACES

Android smartphones

Three of the latest devices battle it out

PROS
☑ Excellent camera
CONS
☒ Slightly bigger than its rivals

PROS
☑ Comparatively low price
CONS
☒ Disappointing camera, no SD

PROS
☑ Slim and super-powerful
CONS
☒ Difficult to unlock

Samsung Galaxy S III

Price: £499.99/$699.99

Get it from: www.samsung.com

Running just behind the HTC One X on raw CPU power is Samsung's latest offering, the Galaxy S III. Its quad-core is a 1.4GHz beast and it's been furnished with other similarly competitive specs: up to 64GB of storage (microSD-expandable to 128GB), a sharp 720 x 1,280 display that puts its predecessors to shame and, of course, an Android 4.0 OS. The Galaxy S III is a slim and tactile smartphone, but also a nose ahead in looks, rivalling the iPhone for its svelte white lines (it's also available in black, in case there was any reason you wanted to play down the fact that you're holding a valuable bit of kit).

The eight-megapixel camera is an ace up its sleeve, snapping photos and taking 1080p videos whose quality approaches the best of compact equivalents. The camera interface is easy to use, it has a distinctly more powerful flash than the iPhone and, despite comparable optics, still seems to take sharper and more colourful pictures. There's nothing that really makes the S III stand out from the competition but, overall, it does have a slight edge.

Verdict: ●●●●●

HTC One X

Price: £459.99/$729.99

Get it from: www.htc.com

Are you looking for bragging rights? Well, how about this: the HTC One X has a 1.5GHz quad-core processor, at least if you live outside the US and certain other countries (otherwise it's a 1.5GHz dual-core). It's the first smartphone to feature this whopper of a multitasking CPU, backed up by a gigabyte of RAM and 32GB of storage. Its base architecture alone knocks its rivals out of the race, but HTC hasn't forged itself a reputation as a leader of Android smartphones based on a handful of geeky statistics alone. The Android 4.0-powered One X houses an eight-megapixel camera that is a worthy replacement for a standard digital compact. It captures full-HD video that, thanks to the blistering quad-core, is stutter-free and you can even take a photo while recording without dropping a single frame.

It's really simple to use too. The HTC One X is a high-end mobile device that can be as complicated as technophiles want it to be, but if you're late getting on the Android smartphone bandwagon, then you won't have any problems feeling your way around this One.

Verdict: ●●●●○

Sony Xperia S

Price: £369/$549.99

Get it from: www.sonymobile.com

Rather than go head to head in the quad-core battle, Sony has opted for a 1.5GHz dual-core CPU in the Xperia S. With this ARM processor technology more readily available, it's meant that not only has Sony been able to get the Xperia S to market quicker, but also at a much more attractive price. For around £100 ($200) less than its competitors, the Xperia S offers a 1,280 x 720 TFT screen, Google Android 2.3 (Gingerbread) and a 12.1-megapixel camera with autofocus and a 16x digital zoom. On paper, the camera makes for a tasty selling point, but while it might be able to capture a higher-resolution shot than, say, the Galaxy S III, it doesn't cope well with low light and the pictures it snaps aren't nearly of the same quality, even if it is superfast.

We're not sure we're fussed with the way the Xperia S looks either: it's comparatively small and light, but the strange transparent bezel at the bottom and its boxy shape do nothing for it. Critically, it's missing a card slot too, so though casual users might get on with it, those who really like to explore their Android phones may want to pass here.

Verdict: ●●●●○

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MAKE A SLINGSHOT

Relive your childhood by creating your own slingshot with some everyday items

1 Collecting

To start we need a small Y-shaped branch. Ideally, it should be thicker at the base than at its forks. Importantly, it needs to be small enough to hold in one hand, yet at the same time quite strong. Dead tree branches are not ideal, as they snap easily.

2 Prepping

Once you've found your branch you need to prep it for its future role as the body of your slingshot. This process will entail you stripping it of any small outlying twigs and leaves and then cutting it down to size – when doing this, try to keep the sling forks in proportion to the handle. Finally, for comfort, you can sand or file down the bark so the handle has a smooth finish.

3 Tubing

Okay, now it's time to prep the sling's elastic action. For best results latex tubing should be used, however a few large elastic bands can also offer decent results. Take the tubing and trim it down to size. Two 30-centimetre (11.8-inch) lengths should be adequate; if they look too long, don't worry, as we will need a bit extra to attach the tubing to both the forks and add the leather strap.

4 Wiring

Next we need to attach the tubing to the forks. Take a knife and carefully score two notches on each fork about five centimetres (two inches) from the tips. The notches should be slight and go 360 degrees around the forks; if they are too deep they may cause the wood to snap when in use. Now take the tubing and wrap an end around each notch and fasten them in place – on the pull-back side – with string. Ensure the tubing is securely attached to both forks before proceeding.

5 Strapping

Finally, we need to create a leather strap for the sling – the seat for the projectile. This is best done with a leather strip, which can either be bought from a craft shop or worked up from an old belt; if you do use a belt that has the added bonus of already having holes punctured in it, which can be used to attach the tubing. If you have just a leather strip, however, simply puncture two small holes roughly 2.5 centimetres (one inch) from either end with a knife and then thread the tubing through before affixing as per step 4.

BUILD A FIRE

With modern lighters and matches starting a wood fire isn't difficult, but building one so that it burns steadily is an art form

Building your own fire in the wild can be fun, but always ensure you put it out completely once you've finished

1. TINDER

To begin we need to gather or create some tinder – that's small dry pieces of material whose job it is to catch the initial flame to generate a fire. Strips of paper, moss, pine needles, grass and dry bark are all ideal tinder material, each easily setting alight and quickly generating a small flame. If no natural tinder is accessible, you can make some wood shavings by carefully stripping down a larger log with a sharp knife.

2. KINDLING

Now we need to collect kindling, by which we mean small dry twigs, sticks and branches. Kindling is important as it will act as a 'middleman' between the tinder and the real fuel of the fire: the wooden logs. Importantly though, kindling with a large surface-to-volume ratio should be used rather than any old material, as this way it can properly fulfil its function of generating an even fire quickly and for the length of time necessary to ignite the denser logs.

3. CUTTING

As with the kindling, the fire's logs should be prepared prior to being dumped on the fire. First, only dry logs should be used, as damp ones will draw excess heat out of the fire and take far longer to set alight. Second, logs of uniform diameter should be used, again to ensure an even burn. Third, if at all possible, logs should be split lengthways with an axe to expose the clean inner wood to the flame, rather than the bark-covered exterior. Finally, get at least double the number of logs you think you'll need; you always need more.

4. CLEARING

Before we actually construct the fire proper, it is good practice to prepare its base and surrounding area. First, clear the ground of any dead leaves or debris and create a circular ring of rocks roughly a metre (four feet) in diameter. You can then create a bed of stones across the area for the fire to sit on – stones are excellent as a base as they retain heat well. Digging a small pit for the fire to sit in will also help protect it from wind and creates natural heat walls. Alternatively, simply start building on the flat ground if it's dry.

NEXT ISSUE
Drive a tank
Build the perfect sandcastle

5. STACKING

Finally it's time to construct the fire. Start with the tinder by placing it in a small central mound at the heart of the circle. Then take your kindling and create a small pyramid with it on top of the tinder, ensuring that small gaps remain throughout to ensure a good supply of oxygen can reach the centre. Ideally, the base of the kindling should be nestled within the outer layer of the tinder, an inch or two in from its outer boundary. At this stage you can now light the tinder. Then once the tinder has passed its flame on to the kindling, stack logs in a lattice around the central pyramid.

[illegible]

WHISTLE WITH YOUR FINGERS

Fed up with not being able to whistle? Well, try this method and become a pro

1 Perfect A

For this to work first we need to create an A-shape with our middle and index fingers. Extend these four fingers and bring your hands together so the two middle fingers' tips touch. At the same time hold down your ring and little fingers with your thumbs.

2 Wet your whistle

Okay now we need to prepare our mouth. To do this wet your lips and then draw them over your teeth. It's important that both your upper and lower lips totally cover your teeth. Don't worry about pressing your lips down too hard as your fingers will help with this.

3 Tongue-tied

This is the hardest part. You now need to pin your tongue back with the A-shaped finger arrangement. To do this, make your A-shape and then place your joined fingers under the tip of your tongue. Next, gently push the tip back slightly until your knuckles reach your bottom lip. Don't worry if you struggle to pin your unruly tongue down – just reposition your fingers until comfy.

4 Seal

With your tongue in place, it's now time to create a seal around your fingers, leaving just a small central hole through which the air can escape.

5 Final whistle

If all instructions have been followed, you should be able to gently blow and generate a whistle. In all likelihood this will not happen immediately, as the positioning of your fingers, tongue and lips needs to be just right and the technique can differ. If you are having no luck, try experimenting with the position of your tongue and remember you should only feel air blowing out through the centre of your mouth across your bottom lip. If you feel air escaping elsewhere, start over.

TEST YOUR KNOWLEDGE

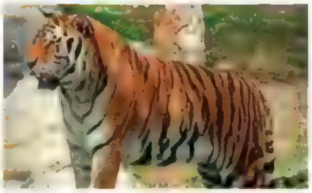
ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

1 What's the name of Richard Branson's deep-sea sub?
A:

2 Who invented and patented the process of rubber vulcanisation?
A:

3 What's the screen resolution of the Samsung Galaxy S III?
A:

4 How heavy is the Curiosity Mars rover in kilograms?
A:



5 Which of the big cats is the best climber?
A:

6 Who led the French army at the Battle of Agincourt?
A:

7 When did Leonardo da Vinci invent his ornithopter flying machine?
A:

8 What percentage of people worldwide are estimated to have some kind of phobia?
A:

9 How many prototypes of the bagless vacuum cleaner did James Dyson build?
A:

10 In what year was the pressurised inhaler first invented?
A:

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> ISSUE 35 ANSWERS

1. 45,500 tons **2.** 120 000 vehicles **3.** 180°C **4.** 100m
5. Pack rats **6.** 15mn°C **7.** 2 **8.** The Black Forest **9.** 2 **10.** 157m

INBOX

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Get in touch!

We enjoy reading your letters every month. So keep us entertained by sending in your questions for the mag, comments on what you like/don't like, or any science-related news you want to share.

FANTASTIC PRIZE FOR LETTER OF THE MONTH!

WOWee ONE™

WIN A WOWEE ONE PORTABLE SPEAKER

This issue's top letter wins a WOWee One Classic portable speaker. This turns any surface into a bass amplifier using gel technology, and is compatible with all iDevices and other mobile gadgets.

Even if we could pull Mars towards Earth, how would we stop *this* from happening?

Letter of the Month

The Mars winch

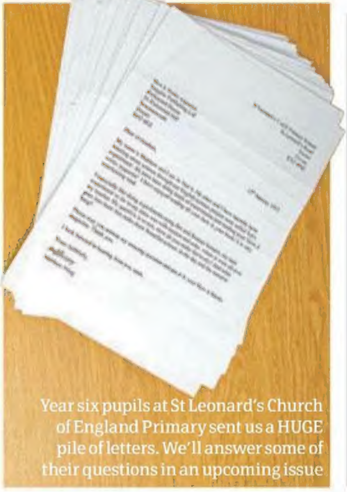
Hi, **How It Works**, I have noticed a few articles on other life in the universe and how the planet needs to be in the habitable zone. If we have overpopulation problems on Earth, why don't we pull Mars into this zone? Because Earth is bigger than Mars and has a larger gravitational force, with all the technology nowadays, we could build a massive winch to pull Mars into the zone. Also, with global warming and all that CO_2, can't we just pipe it into space? I have one final idea before I stop boring you to death: if the ozone is made of O_3, why don't scientists just make more of that and fly it up to the atmosphere?

Owen England

Of course, a good scientist needs to be clever, but a great scientist needs to get creative. Those are some extremely imaginative solutions to world problems, Owen, and even if they aren't necessarily achievable with our current technology, it's exactly the kind of thinking that we like here on How It Works!

The 'Mars winch' in particular got our brains going: if we were able to tie Mars and Earth together with cables and anchors, which were capable of taking the strain, Newton's third law states that for every action there must be an equal and opposite reaction - so by pulling Mars towards the Earth we'd also pull Earth towards Mars. For feeding our imaginations with your ideas, you've won the Letter of the Month prize - congratulations!

Win! A WOWee One portable speaker



Year six pupils at St Leonard's Church of England Primary sent us a HUGE pile of letters. We'll answer some of their questions in an upcoming issue

Weather or not

Hi. I enjoy reading **How It Works** and so does my grandson. Could you please explain what the jet stream is, how it forms and where it comes from? Why is it sometimes out of position - which affects our weather so much - and why does it travel west to east?

Keith

HIW: Earth, Jupiter and other planets all have jet streams. They're caused by the temperature and pressure differences of air masses meeting each other, resulting in strong prevailing winds. The northern jet stream is the one generally referred to by weather forecasters and its direction, as well as changes in its usual seasonal course (such as the low latitude that it has taken over the UK this year), are dictated by a number of factors including the rotation of the Earth.

Hurt feelings

Just wanted to raise a couple of points from issue 34. Page 61 [in the 'How deserts work' feature] describes the Earth's makeup. The last paragraph notes that desert ecosystems are damaged by things like off-road vehicles, drilling and mining. Being a geophysicist in oil and gas exploration who drives a four-wheel drive, I felt a little hurt by that comment. Although it may be true, I think you need to be a little more 'fair' in your generalisations. By this I mean that the top of the page contains a banner that says, 'Solar panels covering just 0.3 per cent of the Sahara would generate enough clean energy to power Europe'. Solar panels are not clean - they are in fact very 'oil-energy' intensive in their manufacture. And covering 0.3 per cent of the Sahara Desert would probably have more damaging effects to the ecosystems than all the four-wheel drives in the US driving around the Sahara each day (not that you were implying we actually put solar panels in the desert). I do think from an oil and gas industry perspective, we all should be a little more open-minded and not simply consider mining and drilling as bad and solar panels or hydro/wave energy as good. I am sure you get my point by now.


Our number one feline fan, Wilson, enjoying the atoms feature in **HIW** issue 34

Apart from that I am on my second year's subscription, and do enjoy the magazine very much. Keep up the good work. I do like the online videos and thank you for providing exposés on famous scientists like Sagan and Tesla as I had suggested in one of my previous emails that was published last year.

Paul, Perth, Western Australia

HIW: Point taken, Paul. While the extraction of fossil fuels and their use does have a negative impact on the environment that 'green' energy tends to avoid, there's an appropriate time and place to mine for coal, drill for oil, use solar panels and, of course, drive off-road vehicles.

Feline fan

I buy **How It Works** every month and each issue is so fantastic that my cat Wilson likes it too! We loved the article about '10 space myths' and can't wait to read about ice volcanoes and space jetpacks. Thanks for the knowledge.

Tasmin Bucknall

HIW: Hi, Tasmin, we knew we were reaching people with How It Works, but we didn't realise we were a hit with the feline community too. Perhaps it was our article about domestic cats in HIW issue 33 (page 64) that proved the hook for Wilson? Glad you're both enjoying the mag.

Going for cold

Please can you answer this question: why do we shiver when it's cold? My goal is to go to the Olympics in 2020 and swim, however I get cold in the water and start to shiver, so would like to know why.

Rohan Penney, 10

Space speeding

Just a note about an article in issue 33, concerning the maximum speed an object can travel in space. This article was correct but not quite complete, as it might lead some readers to think that it would take a spacecraft travelling near the speed of light just over x years to go x light years. Well, yes – as measured by someone watching from Earth.

I suspect that the reader who asked you the question (Penny McWalters) really wanted to know how far she could travel through space in her lifetime. The answer is very surprising to those who don't know about time dilation – travelling with a constant 1 g acceleration, it would only take 29 years on ship to travel to the Andromeda galaxy, which is just over 2 million light years away! Unfortunately, you'd also find that, when you got back home, the Earth was millions of years older, and that (almost) everything you ever knew was long gone… Now all we have to do is build the starship!

Dr Paul R Bowden, BSc BSc MSc PhD MInstP (lecturer in Computing at Nottingham Trent University)

What's happening on… Twitter?

We love to hear from **How It Works**' dedicated readers and followers, with all of your queries and comments about the magazine and what you'd like to see explained. Here we select a few of the most interesting tweets that we've received in the last month.

vjb1975
@HowItWorksmag
Your brain knows what your body is going to do six seconds before it does it. That's right creeped me out!

VirtuallyGeeky
@HowItWorksmag
Glad I never hit a solid wall at 200km/h [124mph] – insane 200km/h crash test!

StarryEyedTruth
@HowItWorksmag
Not had a chance to have a proper look @ issue 35, only managed a flick-through, but it looks the best yet! The cover is awesome

scott_gamer
@HowItWorksmag
Picked up the new issue this morning. The most fascinating bit for me is about how parrots are able to imitate human speech

BlueSilence
@HowItWorksmag
I enjoyed reading 'A-Z of the Ancient Greek Olympics' [issue 34] :-) I really do like your illustrations and images that you pick each issue as well

TheHubbard
@HowItWorksmag
@HowItWorksmag New @HowItWorksmag arrived, still haven't managed to read the last few mags yet! #toomanyexams! And the new space mag advertised looks fab

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Web: www.imagine-publishing.co.uk
www.howitworksdaily.com
www.greatdigitalmags.com

Magazine team

Editor **Helen Laidlaw**
helen.laidlaw@imagine-publishing.co.uk
☎ 01202 586215

Editor in Chief **Dave Harfield**
Features Editor **Robert Jones**
Features Editor **Ben Biggs**
Art Editor **Helen Harris**
Senior Sub Editor **Adam Millward**
Head of Publishing **Aaron Asadi**
Head of Design **Ross Andrews**

Contributors
Mike Anderiesz, Aneel Bhangu, Shanna Freeman, Nicolle Rager Fuller, Tom Harris, Rik Sargent, Adam Smith, Luis Villazon, Nigel Watson, Jonathan Wells

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hang.deretz@imagine-publishing.co.uk

Account Manager Liz Tucker
☎ 01202 586431
liz.tucker@imagine-publishing.co.uk

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Founders
Group Managing Director Damian Butt
Group Finance and Commercial Director Steven Boyd
Group Creative Director Mark Kendrick

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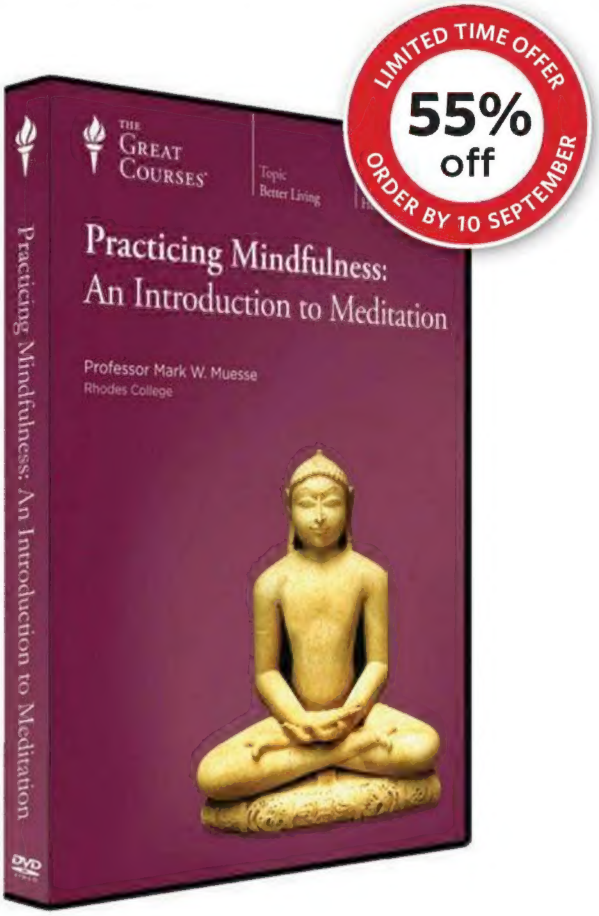

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